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Advanced Manufacturing Development of a Composite Empennage Component for L-1011 Aircraft

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QUARTERLY TECHNICAL REPORT NO. 1[illegible]

For the period 1 July 1978 through 30 September 1978

Lockheed Corporation
Lockheed-California Company
[illegible]
[illegible]

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Advanced Manufacturing Development of a Composite Empennage Component for L-1011 Aircraft

DRL 003

QUARTERLY TECHNICAL REPORT–NO. 11

This report is for the period 1 July 1978 through 30 September 1978

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13 October 1978

Prepared for Langley Research Center

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FOREWORD

This report was prepared by the Lockheed-California Company, Lockheed Corporation, Burbank, California, under contract NAS1-14000. It is the 11th quarterly technical report, covering work completed between 1 July 1973 and 30 September 1973. The program is sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. The program manager for Lockheed is Mr. Fred C. English. Mr. Louis F. Vosteen is project manager for NASA, Langley. The technical representative for NASA, Langley is Mr. Herman L. Bohon.

SUMMARY

The technical activities performed in this reporting quarter and documented in this report are related to tasks associated with Phase II, Phase III, and Phase IV of the Advanced Composite Vertical Fin (ACVF) Program. These tasks include the following: in Phase II, Component Definition, Material Verification, Process Verification, and Concept Verification; in Phase III, Spar Fabrication and Test Support; and in Phase IV, Component Tool Development. The discussion of technical activities related to these tasks is presented separately for each of the ACVF team members. The team member responsibilities are as follows: prime contractor, Lockheed-California Company for the covers, ribs, and overall design; and subcontractor, Lockheed-Georgia Company for the spars and box assembly.

Work continued during the reporting period toward the development of tooling and processing concepts required for a cocured hat/skin cover assembly. A plan has been developed and implemented to develop the process for using preimpregnated T300/5208 with a resin content of 34 ± 2 percent by weight. Use of this material will result in a simplified laminating process because removal by bleeding or prebleeding will no longer be required. The approach to this task basically consists of fabricating and testing flat laminated panels and simulated structural panels to verify known processing techniques relative to end-laminate quality. The flat panels were used to determine air bleeding arrangement and required cure cycle. Single and multihat-stiffened panels have been fabricated using the established air bleeding arrangement and cure cycle with the resulting cured parts yielding excellent correlation of ply thickness with all surfaces clear of porosity and voids.

The last of the spar ancillary test specimens was tested at the Lockheed-Georgia Company during this reporting period. Two rear stub spar specimens were tested, one at room temperature-dry (RTD) and the other at 180°F pre-conditioned to 1 plus percent moisture. The RTD specimen sustained 244 percent of design limit load, and the wet specimen, tested at 180°F, failed at 272 percent of design limit load.

The full-size, front spar tool was completed and proofed with a fiberglass part. The fiberglass part used to check the tool was impregnated with 5208 resin and cured using the same cycle as specified for the all-graphite spar. Heat-up and temperature distributions inside the tool followed the process bulletin requirements and a close tolerance, high quality fiberglass part was produced by the tool. The first, full-length, all graphite-epoxy front spar will be cured in the autoclave during the next reporting period.

The indicated weight saving for the ACVF is currently at 27.9 percent (239.1 pounds) including a 10-pound growth allowance. Without the growth allowance, a weight saving of 29.0 percent (249.1 pounds) is anticipated. Composite material utilization is currently predicted to be 77.8 percent of the redesigned fin box weight.

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SECTION 1
INTRODUCTION

The broad objective of the Aircraft Energy Efficiency (ACEE) Composite Structures Program is to accelerate the use of composite structures in new aircraft by developing technology and processes for early progressive introduction of composite structures into production commercial transport aircraft. This program, as one of several which are collectively aimed toward accomplishing that objective, has a specific objective: to develop and manufacture advanced composite vertical fins for L-1011 transport aircraft. Laboratory tests and analyses will be made to substantiate that the composite fin can be safely and economically operated under service loads and environments and will meet FAA requirements for installation on commercial aircraft. A limited quantity of units will be fabricated to establish manufacturing methods and costs. The Advanced Composite Vertical Fin (ACVF) will make use of advanced composite materials to the maximum extent practical and weigh at least 20 percent less than the metal fin it replaces. A method will be developed to establish cost/weight relationships for the elements of the composite and metal fins to establish cost effective limits for composite applications.

The ACVF to be developed under this program will consist of the entire main box structure of the vertical stabilizer for the L-1011 transport aircraft. The box structure extends from the fuselage production joint to the tip rib and includes the front and rear spars; it is 25 feet tall with a root box chord of 9 feet and represents an area of 150 square feet.

The primary emphasis of this program is to gain a high level of confidence in the structural integrity and durability of advanced composite primary structures. An important secondary objective is to gain sufficient

knowledge and experience in manufacturing aircraft structures of advanced composite materials to assess properly its cost-effectiveness.

The duration of this program is 76 months, with completion scheduled for May 1983. The master schedule for this program is shown in Figure 1-1. The program is organized in four overlapping phases: Phase II - Design and Analysis; Phase III - Production Readiness Verification Tests (PRVT): Phase IV - Manufacturing Development; and Phase V - Ground Tests and Flight Checkout. Phase I was completed during 1976.

The Lockheed-California Company has teamed with the Lockheed-Georgia Company in the development of the ACVF. Lockheed-California Company, as prime contractor, has overall program responsibility and will design and fabricate the covers and the ribs, conduct the PRVT program, and conduct the full-scale ground tests; Lockheed-Georgia Company will design and fabricate the front, rear, and auxiliary spars, and assemble the composite fin at their plant in Meridian, Mississippi, where the present L-1011 vertical fins are assembled.

Phase I, Engineering Development, has been completed; and Phases II, III and IV are in progress.

Phase II, Design and Analysis, consists of completing the detail design and analysis, characterization of the T300/5208 material system, initiating producibility studies, and conducting material, process, and concept verification tests. Phase III, Production Readiness Verification Testing (PRVT) is designed to provide information to answer the following questions:

- What is the range of production qualities that can be expected for components manufactured under conditions similar to those expected in production, and how realistic and effective are proposed quality levels and quality control procedures?
- What variability in static strength can be expected for production quality components, and are the margins sufficient to account for this variability?

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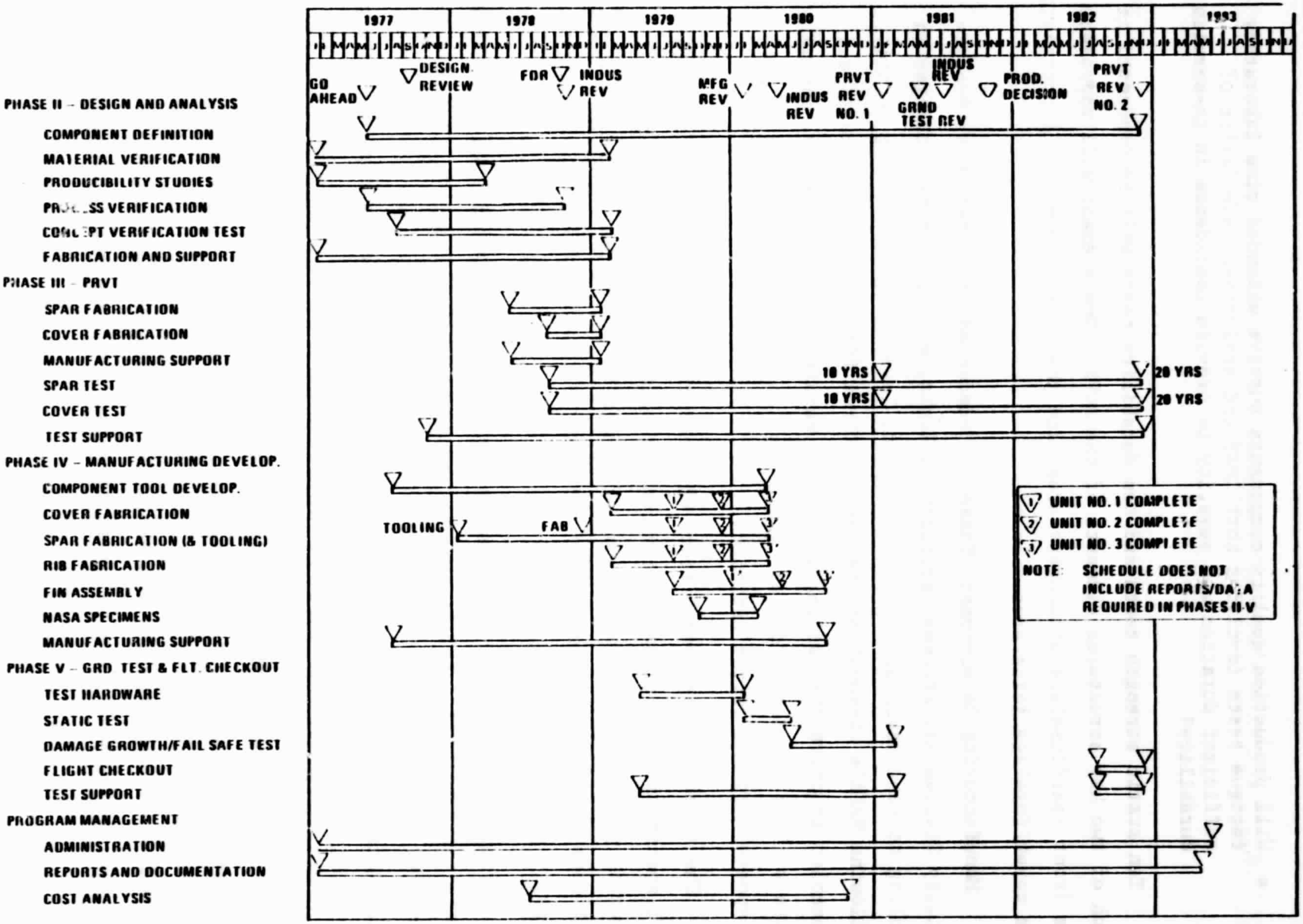

Figure 1-1. ACVF Program Master Schedule

- Will production quality components survive extended time laboratory fatigue tests involving both load and environment simulation of sufficient duration and severity to provide confidence in in-service durability?

Ten static strength tests and ten durability tests will be conducted on each of two key structural elements of the ACVF. One element will represent the front spar/fuselage attachment area, and the other element will represent the cover/fuselage joint area.

Manufacturing Development, Phase IV, conducted concurrent with Producibility Studies and Process Verification Tasks, will accommodate changes in tooling to take advantage of development of low-cost manufacturing methods. Following NASA's approval of the design, three fins will be fabricated and assembled to prove the design, methods of manufacture, and quality. Actual costs will be documented during fabrication and components will be weighed to update cost and weight estimates.

The manufacturing cost history obtained through the fabrication of the PRVT specimens in a production environment will provide cost data for a starting point for this application of composite structure. Together, they will form the ba 's for reasonably confident estimates of future production costs.

Ground tests will be conducted on two full-scale fin box beam structures mounted on simulated fuselage support structures during Phase V. The test plan will include static tests, ultimate load and failure load tests on one GTA. Damage growth tests to two lifetimes, and fail-safe and residual strength tests will be done on the second GTA. Repair techniques for in-service maintenance and inspection will be employed throughout tests. Test results will be used to verify the analytical, design, and fabrication procedures; and are essential inputs to the FAA for certification of the aircraft with the ACVF installed. Certification will be based on satisfying both static strength and fail-safe requirements. FAA certification flight tests will also be conducted during this phase in order to obtain full FAA certification.

Throughout this program, technical information gathered during performance of the contract will be disseminated throughout the aircraft industry and Government. The methods used to distribute this information will be through Quarterly Reports, which will coincide with calendar quarters; and Final Reports of each phase to be distributed at the completion of each phase. All test data and fabrication data will be recorded on Air Force Data Sheets for incorporation in the Air Force Design Guide and Fabrication Guide for Advanced Composites. Oral Reviews will also be conducted at NASA, Langley to acquaint the aircraft industry and the Government with progress of the program.

SECTION 2

PHASE II - DESIGN AND ANALYSIS OF RIBS AND COVERS

Phase II, design and analysis of the ribs and covers, comprises the main engineering effort of Lockheed-California Company in the design, development, and fabrication of the eleven ribs and two cover assemblies for the L-1011 composite vertical fin. The engineering effort during this reporting period covered four tasks: component definition, material verification, process verification, and quality assurance.

2.1 COMPONENT DEFINITION

Component definition covers the detail design and structural analysis of the selected rib and cover configurations.

2.1.1 Detail Design

The detail design of the ribs and covers has been completed.

2.1.1.1 Weight Status

The current weight status is shown in Table 2-1. A weight savings of 27.9 percent (239.1 pounds) is currently being predicted including a 10 pound growth allowance. Without the growth allowance, a weight savings of 29.0 percent (249.1 pounds) is anticipated. Composite material use is currently predicted to be 77.3 percent of the redesigned fin box weight. A summary of weight changes since the last quarterly report is presented in Table 2-2. A weight-time history for the composite fin is provided in Figure 2-1.

2.2 MATERIAL VERIFICATION

This task is structured to develop the material properties of the T300/5208 unidirectional tape material system to derive design allowables for the ACVF.

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TABLE 2-1. CURRENT WEIGHT STATUS

Item	Metal Design Total Weight (lb)	Composite Design			Weight Change
		Target Weight (lb)	Total Weight (lb)	Composite Mat'l Wt (lb)	
Covers	460.4	368.4	351.7	333.9	-2.0
Spars	199.0	132.0	117.2	87.9	-0.3
Ribs	153.3	131.8	107.0	46.1	-1.0
Assembly Hardware	35.4	16.7	14.6	-	+0.2
Protective Finish	9.6	9.6	9.6	-	
Lightning Protection	-	15.5	0.0	-	-14.2
Installation Penalty	-	5.0	8.5	-	
Design Growth Allowance	-	-	10.0	10.0	-14.0
Total Fin Predicted Delivery Weight - lb	857.7		618.6	477.9	-31.3
Weight Saving = lb			239.1		
Percent Weight Saved			27.9		
Percent Composite Material				77.3	
Total Fin Current Indicated Weight - lb (Predicted Less Growth)		679.0	608.6 29.0	467.9 76.9%	
Current Indicated Weight of Redesigned Component	8.25.4 ⚠1		587.4	(28.8% Weight Saved) ⚠2	

Weight Basis: 5% EST, 95% CALC, 0% ACT

⚠1 Total metal design weight less weight of components not redesigned

⚠2 Based on redesigned metal components

TABLE 2-2. SUMMARY OF WEIGHT CHANGES

Item	Weight Change (lb)		Remarks
	Total	Composite	
Covers	+4.2	0	Add 17 MIL aluminum tape electrical bonding strap along L.E. and T.E. of covers.
	-2.6	-2.6	Remove fiberglass insulator ply from outer surface of covers.
	-2.7	-2.7	Revise configuration of corner reinforcing straps of the hat stiffeners.
	-1.5	-2.1	Miscellaneous changes
Spars	-0.3	0	Miscellaneous changes
Ribs	-1.0	-3.5	Revised calculations per latest drawings
Hardware	+0.2	0	Revised calculations per latest drawings
Lightning Protection	-14.2	0	Deleted
Design Growth Allowance	-14.0	-14.0	Revised to reflect design status
Total	-31.9	-24.9	

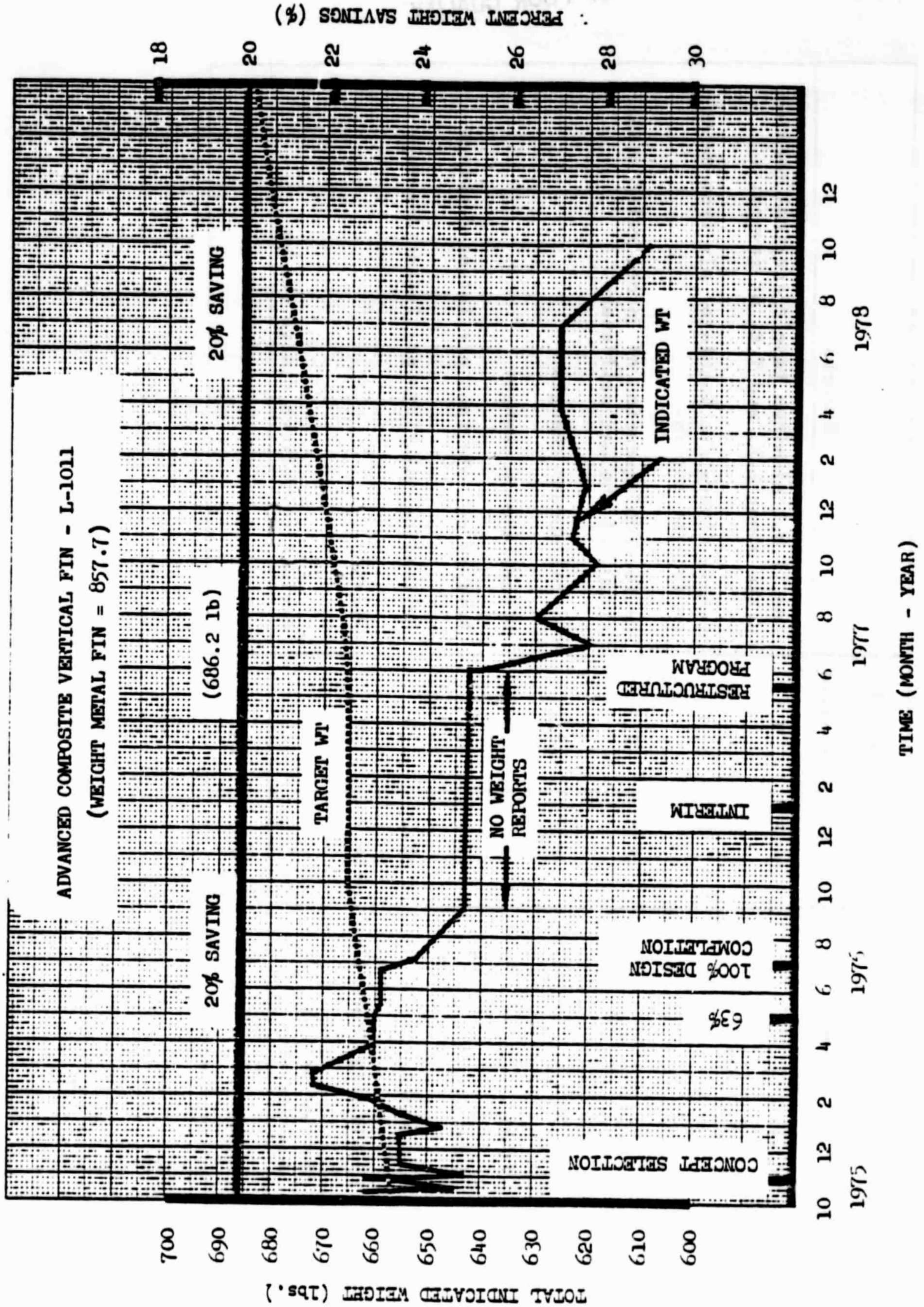

Figure 2-1. Weight-Time History

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CALIFORNIA COMPANY

2.2.1 Evaluation of Detect Tolerance in Composites - Test Item H12B

The object of this test item is to assess the tolerance to defects of T300/5208 composite laminates as used in the ACVF. The test program involves fabrication of a laminate containing known size and position defects. The laminate is then machined into coupons for spectrum fatigue testing and identifying the largest defect that can survive four lifetimes of test.

The test plan was to initiate testing on specimens that had a 1-inch diameter defect (0.0005-inch thick Kapton) imbeded at the midplane of the specimen, between the eight and ninth ply, and a similar 1-inch diameter near surface defect between the second and third ply.

If failure occurred prior to the 4-lifetime duration, the size of the defect would be reduced by 0.25-inch increments until the maximum size defect that could survive the four-lifetime spectrum test was determined.

Prior testing indicated that a 1 inch diameter defect would survive the four lifetimes of spectrum fatigue without growth from the defects. The second phase of this test was initiated in the previous quarter and consists of testing five specimens for four lifetimes of spectrum fatigue while the temperature is cycled from $-65^{\circ}F$ to $180^{\circ}F$ at humidities from ambient to 100 percent RH. The specimens were previously conditioned for 1 percent moisture pick up.

Three coupons have completed the four lifetimes of test with no apparent growth from the defects. The fourth specimen is now in test and has so far completed approximately two lifetimes with no apparent damage growth.

2.3 PROCESS VERIFICATION

2.3.1 Materials and Producibility Studies

A plan has been developed and implemented to develop the process for using preimpregnated T300/5208 with a resin content of 84 ±3 percent by weight. Use of this material will result in a simplified laminating process because removal by bleeding or prebleeding will no longer be required. The approach to this task basically consists of fabricating and testing flat

laminated panels and simulated structural panels to verify known processing techniques relative to end-laminate quality. The flat panels were used to determine air bleeding arrangement and required cure cycle. Single and multihat-stiffened panels have been fabricated using the established air bleeding arrangement and cure cycle.

The technical approaches being followed to develop a molding process for low-resin content prepreg has been prepared and implemented in this reporting period.

2.3.1.1 Flat Panel Studies

Three panels were fabricated using air bleeding systems developed for 16 ply and 32-ply panels.

The resin weight percent, percent voids and moisture content of the (three) panels based on a 2-inch edge strip cut from the 24 inch length of the panels are as follows:

Panel No.	Resin Weight Percent Average	% Voids	Moisture 2-Hr 180°F
1 16-ply	26.04	0.34	0.75
2 16-ply	25.32	0.49	0.13
3 32-ply	32.40	0.0	0.09

With the various methods of air bleeding, the 16 and 32-ply panels have achieved consistent ply thickness which are within the specifications of 4.6 of 4.6 to 5.3 mils/ply.

2.3.1.2 Single Hat-Stiffened Panel Assembly

The detail preplied laminates for the skin and hat were laid up in kit-form ready for assembly.

The preplied segments of the hat readily form to shape on the male tool with hand forming and with minimum rub in place transferred to the female caul plate with the air bleeding system developed. The holding straps work very good in holding the assembly in the caul plate as it was rotated and placed in position on the skin laminate.

Figure 2-2 shows the hat assembly with the air bleeding materials and the steel caul with the enclosed mandrel. The turnover straps (nonporous) armalon have been positioned spanwise at approximately every 10 inches to 12 inches. The air bleeding materials used for this panel assembly are: Top surface:

(Laminate)	Lower Surface (Laminate)
• Nylon peel ply	• Nylon Peel ply
• Porous armalon	• Porous armalon
• Vac Pak film (PVF)	• Vac Pac film (PVF)

Figure 2-2. Hat Assembly with Air Bleeding Materials and Steel Caul

Upon completion of the cure and a review of the bagged assembly indicated the breather plies (181 glass) had absorbed a certain amount of resin that have edge bleed from the part as shown in Figure 2-3.

Removal of the bagging material and the peel ply showed a very good part surface with no resin rich areas on the part, see Figure 2-4. Very good part/tool definition of the hat configuration was achieved. Removal of the inflatable rubber mandrel caused tears in the rubber. Apparently the previous rough spots on the mandrel surface adhered to the resin causing added resistance to the removal process. A cross section cut at the end of the panel is shown in Figure 2-5. This hat-stiffened panel was cut into three coupon specimens, two ends and one center approximate size 5 inches by 12 inches.

Hat-Stiffened Panel Test Results

Dimensional Check - A detail dimensional check was made by Quality Assurance. Figure 2-6 describes the dimensions which indicate that excellent correlation of the ply thickness has been achieved over the cross section of the three specimens in comparison with the specified 4.6 to 5.3 mils/ply thickness range.

NDI Check - The ultrasonic examination of the skin surface and the hat flange/skin interface bond indicated that all surfaces were clear of porosity and voids.

Physical Mechanical Properties - A resin check of the skin under the hat crown indicated an average resin content of 28.5 weight percent. The mechanical properties were acceptable.

Lessons Learned to Date on Hat Stiffened Panel - Process Method I -

- Edge bleeding is a problem on small sub-scale panels.
- On multi-stiffened panels, edge bleeding of hat at edge of flanges may be a problem which may require extra bleeder material between the hats to avoid resin rich skins.

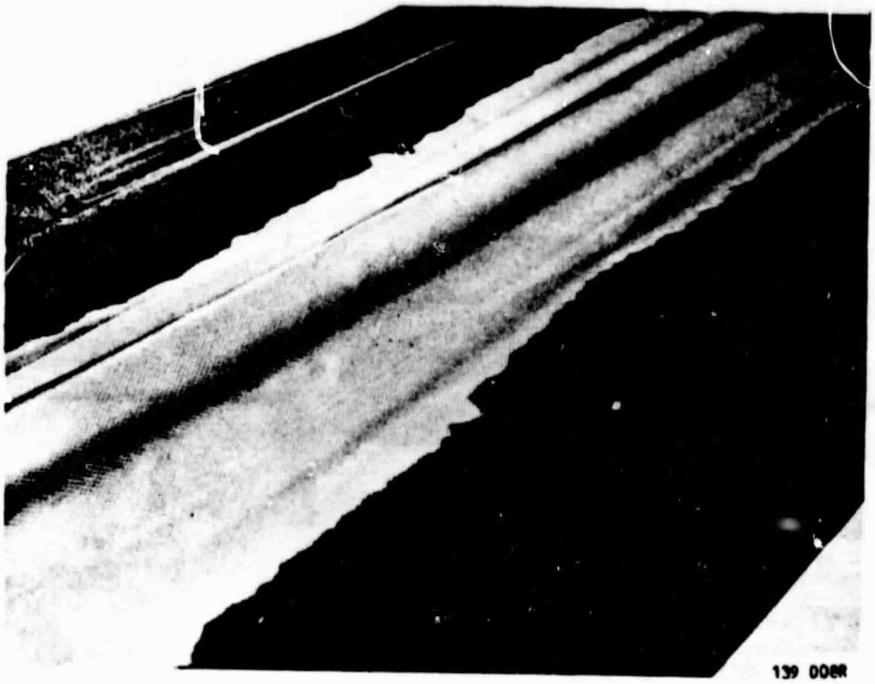


Figure 2-3. Edge Bleeding of Resin into Breather Plies (181 Glass Cloth)

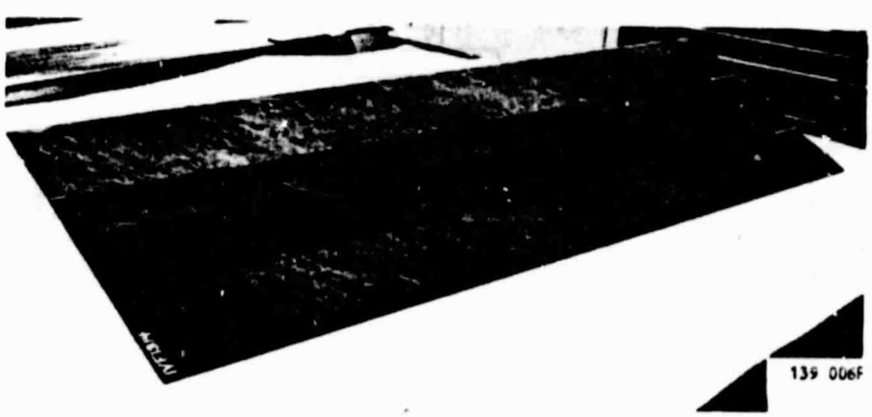


Figure 2-4. Hat-Stiffened Panel Fabricated from Low-Resin Content Prepreg Material

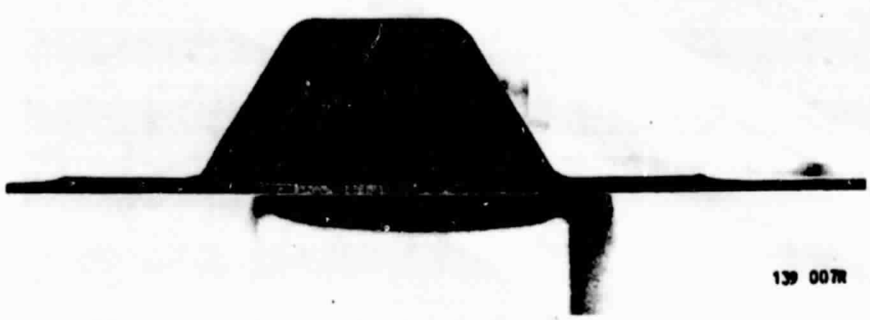
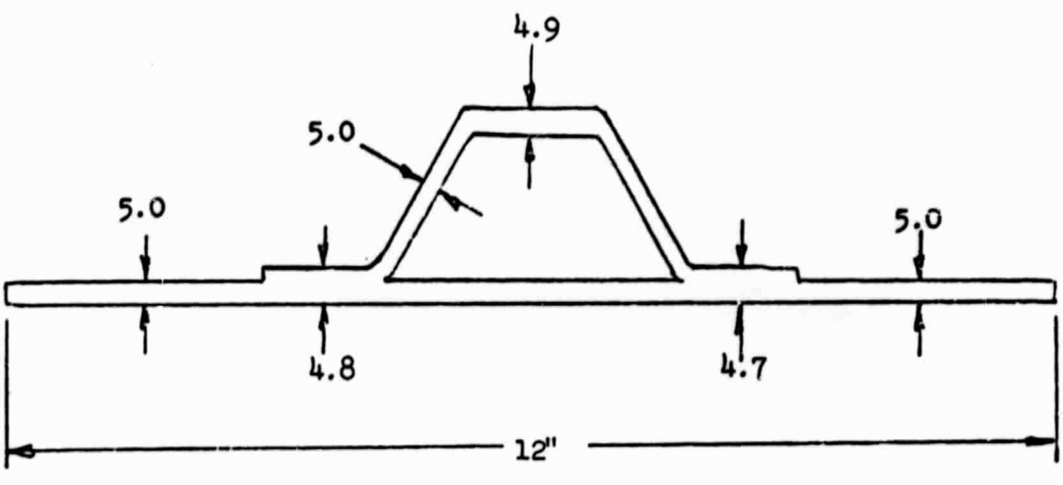


Figure 2-5. Cross Section of Hat-Stiffened Panel



VALUES SHOWN ARE MILS/PLY AS AN AVERAGE TAKEN AT THREE CROSS SECTION ALONG THE 39 INCH SPAN OF THE PANEL.

Figure 2-6. Dimensional Check

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- Inflatable mandrel - caul plate tool concept appears to be adaptable to single stage curing of low resin prepreg.
- The assembly procedure described indicated that it could readily be utilized for production of the full-scale skin cover assembly.

Physical and Mechanical Properties - The physical and mechanical properties for this panel are shown in Table 2-3. The data shown indicates that the values in general meet the process specification except the SBS (Short Beam Shear) of the skin are a little low. However, a 16-ply specimen from the flat skin panel 1 study (same processing) was post-cured for 1 hour and the SBS average was 8.0 ksi and the compression 85.9 ksi. Therefore, on future use of this cure cycle, an additional 1 hour at 355°F may be considered.

2.3.1.3 Hat-Stiffened Panel 2 (IVF 1326)

This panel was assembled from the preplied kit materials, which had been in the freezer for about 10 days. The surface tack of the material was good and the hat shape was easily formed on the tools using hand pressure and rubbing (Teflon) blade tools.

The air bleeding system was modified for this panel to eliminate the peel ply on the hat surface of the panel assembly and to use a gas porous

TABLE 2-3. SINGLE HAT-STIFFENED PANEL 1-PHYSICAL AND MECHANICAL PROPERTIES (IVF 1314)

Locations	R.C.	S.G.	SBS R.T.	SBS (WET)	Comp. R.T.	Comp. (Wet)
Skin	28.9	1.58	5.8	5.2	82.7	75.5
Skin Under Hat	28.5	1.58	7.6	7.2	75.9	79.3
Hat/Crown	28.7	1.59	9.3	10.2	101.7	79.3

R. C. = Resin Content Wt.%
S. G. = Specific Gravity
SBS = Short Beam Shear ksi
COMP. = Compressive Strength ksi

film (A4000P3). This film (A4000P3) has very small diameter pin holes spaced at 3/8-inch centers to allow gas volatiles to escape. In addition, silicone edge dams were used to control edge bleeding during cure.

The elimination of the peel ply from the hat surface of the panel would eliminate the cost of removing it and eliminate the possibility of damaging the surface during removal particularly on the full scale covers. This approach may increase the resin content of the hat 1 to 1-1/2 Wt% by elimination of the peel ply. However, the porous armalon will absorb some resin and is easily removed after cure. The panel was cured using the same cure cycle as for panel 1.

A considerable amount of resin was collected in the breather ply. Apparently, the (A4000P3) film did not stop the resin from flowing though the tiny pin holes into the porous armalon ply. If this air bleeding system is tested again, it is recommended that an additional solid film Vac Pac be used over the armalon ply to prevent bleeding into the breather ply. Also, the silicone edge dams restricted the edge bleeding but also contributed to forcing the resin to flow through the (A4000P3) film pin holes. The top surface of the panel has a shiny finish with a few mark-off areas caused by the difficulty of smoothing out the thin (A4000P3) film during the bagging operation.

Figure 2-7 indicates the ply thickness values that were obtained at the center and each end of the panel. The ply thickness is averaging slightly higher than panel 1 which indicates increased resin content.

The physical and mechanical properties are described in Table 2-4. The resin contents are above the specified value (26 to 30 weight percent). However, the mechanical properties are very good for both RF and Wet. No additional cure time at 355°F and/or post cure was used to obtain these values.

2.3.1.4 Multihat-Stiffened Panel 1 (IVL 1330)

Two kits of preplied material were laid up for the skin, hat webs, hat crown and rib doublers. The prepreg material was batch number 1221 with an average resin content of 33.4 weight percent.

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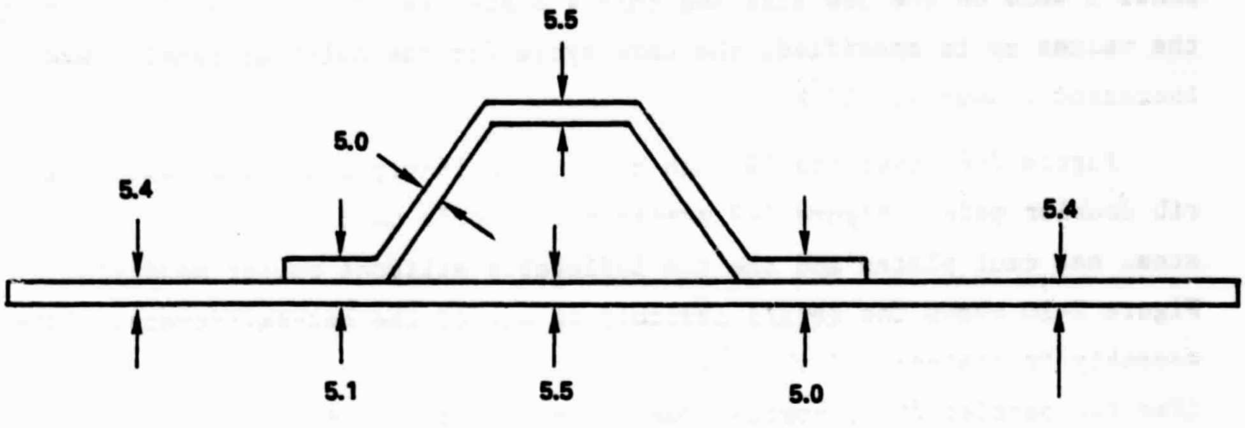

VALUES SHOWN ARE MILS/PLY AS AN AVERAGE TAKEN AT THREE CROSS SECTIONS ALONG THE 39 INCH SPAN OF THE PANEL.

Figure 2-7. Dimensional Check, Hat-Stiffened Panel 2 (IVF 1326) Specified Range (4.6 to 5.3 Mils/Ply)

TABLE 2-4. SINGLE HAT-STIFFENED PANEL 2 - PHYSICAL AND MECHANICAL PROPERTIES (IVF 1326)

Locations	R.C.	S.G.	Voids	SBS R.T.	SBS (Wet)	COMP. R.T.	Comp. (Wet)
Skin	31.4	1.569	-0.1	8.5	9.5	88.9	89.4
Skin Under Hat	34.7	1.551	-0.1	10.0	9.9	87.4	89.8
Hat/Crown	30.6			13.5	13.4	110.7	

R. C. = Resin Content Wt%
S. G. = Specific Gravity
SBS = Short Beam Shear ksi
COMP. = Compressive Strength ksi

The process air bleeding system and cure cycle were similar to the single hat-stiffened panel 1. However, since some of the mechanical properties of panel 1 were on the low side and that a post-cure of 1 hour at 350°F brought the values up to specified, the cure cycle for the multihat panel 1 was increased 1 hour at 355°F.

Figure 2-8 shows the 18 inch by 40 inch 16-ply skin panel with the rib doubler pads. Figure 2-9 presents the tools used composed of the two steel hat caul plates and the two inflatable silicone rubber mandrels. Figure 2-10 shows the detail assembly of one of the hat-stiffeners. This assembly is composed of the steel caul plate with the air bleeding system (Vac Pac barrier film, porous armalon and nylon peel ply) over the hat section laminate layup. Figure 2-11 shows the hat section assembly located on the skin cover laminate. The armalon strips are pulled out as soon as the hat assembly is properly positioned. Figure 2-12 is a view of the bagged assembly with the 181 glass breather plies over the top of the assembly and the vacuum bag. All corner edges were checked for bridging. Figure 2-13 presents the finished cured top view of the multihat panel. This shows excellent tool surface definition of the hat configuration and the rib pads. Figure 2-14 is an end view close up of one of the hat sections, again showing very good internal/external tool definition of the hat configuration. Also, the hat flange/skin interface shows an excellent bond.

The overall quality of this panel was very good indicating that the basic processing for the low-resin content single cure system is reproducible for this size panel configuration. The ultrasonic check indicated that the panel met the requirements of the process specified. Three very small area spots showed up on the hat flanges. These will be microanalyzed to determine if these could be voids/delaminations. A diamond saw cut through one of these spots, viewed with a 25x glass, did not show any delaminations. Figure 2-15 shows the center coupon number 2 cross section indicating the ply thicknesses at the various points. The average thickness of this cross section cut is 4.7 mils/ply which is similar to the thickness per ply achieved in the single hat-stiffened panel 1.

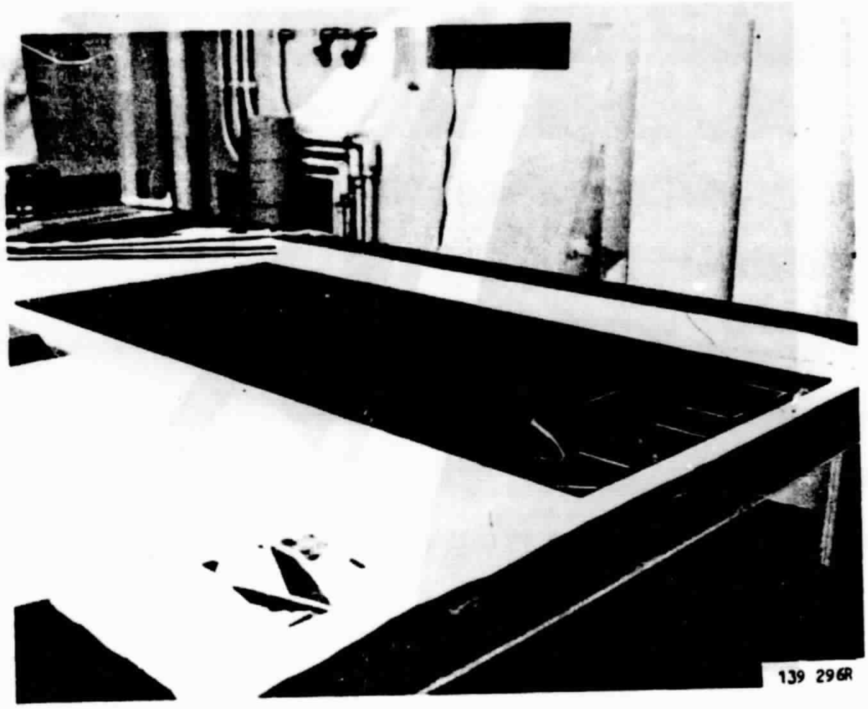

Figure 2-8. Skin Layup

Figure 2-9. Caul Plates and Inflatable Mandrels

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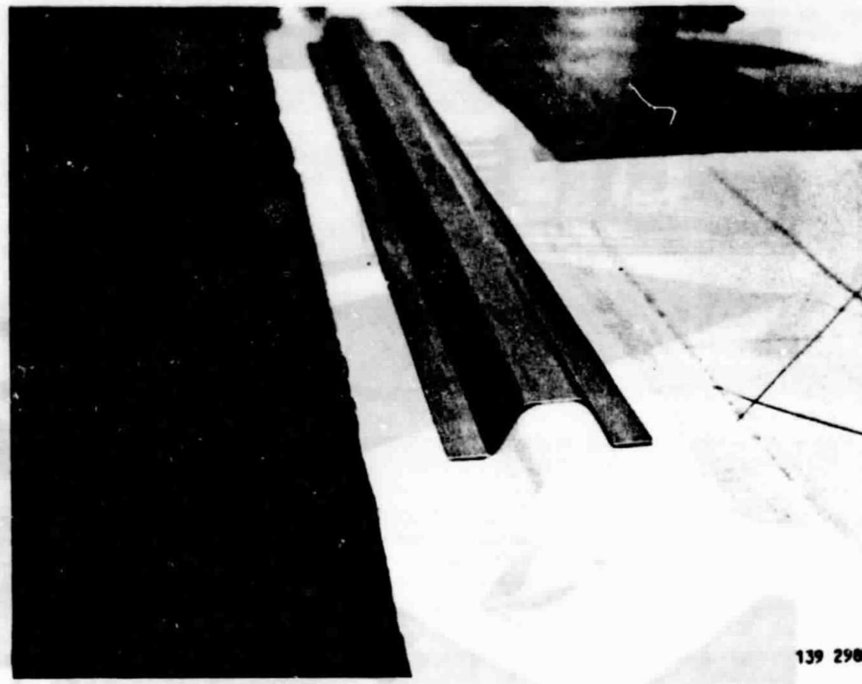

Figure 2-10. Hat Stiffener Layup

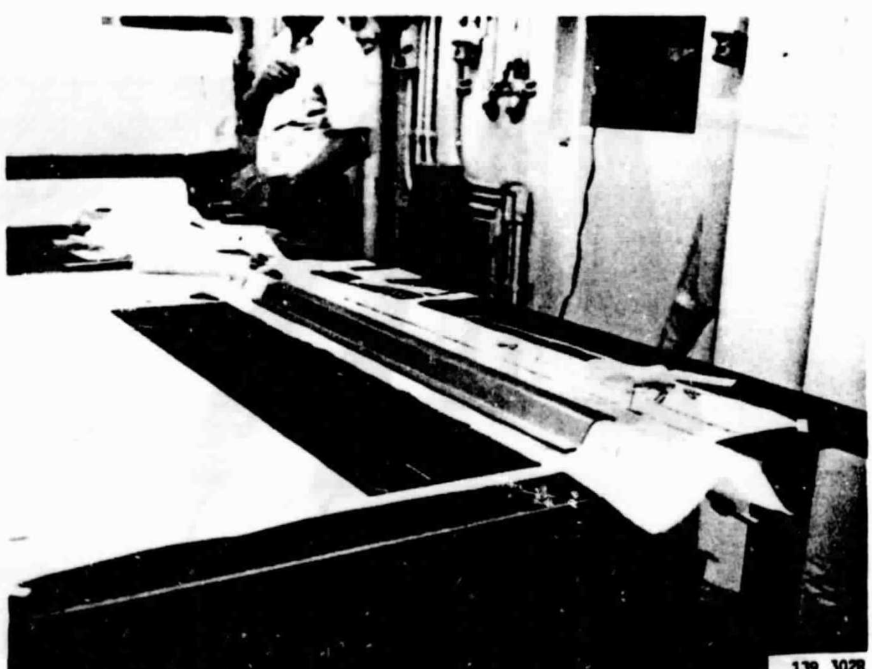

Figure 2-11. Hat Located on Skin

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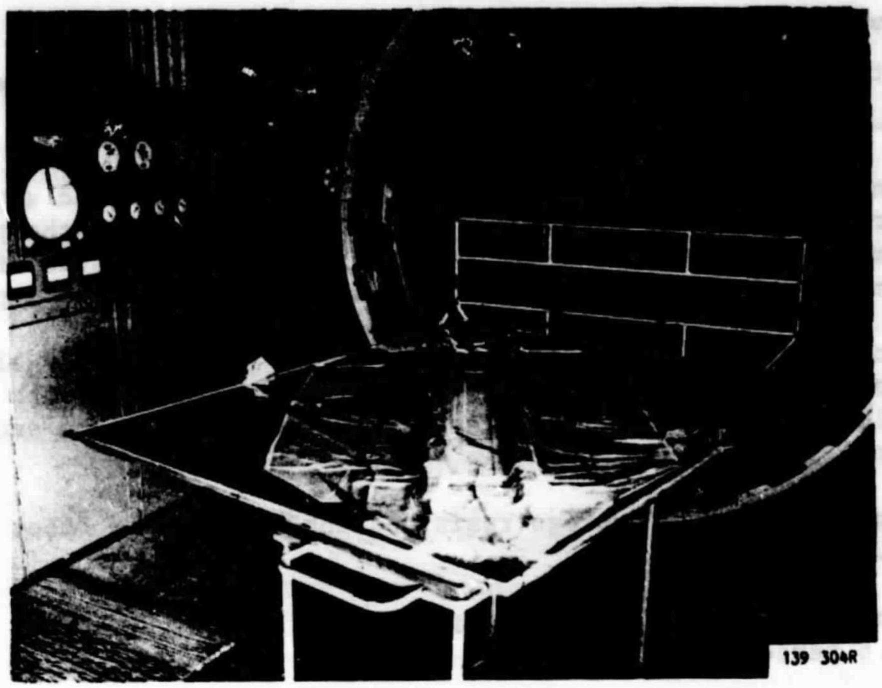

Figure 2-12. Bagged Assembly

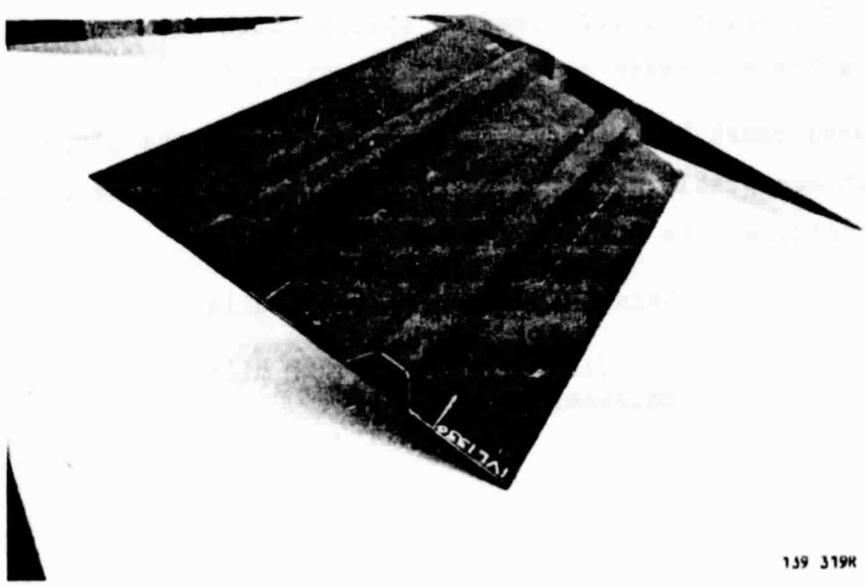

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Figure 2-13. Cured Part

To investigate this bleeding problem, two 16-ply flat panel tests were made with the following change to the air bleeding system in order to achieve an increase in resin content.

- Panel (3VF 1332) Air Bleeding Method I - Incorporated a perforated barrier film A4000P3 between the nylon peel ply and the porous armalon for both the upper and surface bleeding system of the laminate. Also, the edge bleeder was changed back to 1-ply mochburg.
- Panel (4VF 1332) Air Bleeding Method III - The nylon peel was removed from the upper surface bleeding system and replaced with the A4000P3 film. The lower surface bleeding system was kept the same as panel (3VF 1332).
- Panel (3VF 1332) average resin content 29.47 Wt% - fiber volume 62.5 percent.
- Panel (4VF 1332) average resin content 30.92 Wt% - fiber volume 61.6 percent.

It was recommended that the next multihat panel should use method I air bleeding system to achieve a higher resin content to improve the mechanical properties.

2.3.1.6 Multihat Panel 2 (VLI 333)

This panel was laid up on the tools using the laminate segment preplied materials. The method I air bleeding system which has shown by flat panel studies to achieve a resin content of approximately 29 to 30 Wt% was used.

The cured panel has good visual appearance and the ultrasonic check indicated an acceptable panel. A dimensional check of the cross section thickness indicated the following averages:

Skin thickness	=	4.93 mils/ply
Hot flange/skin thickness	=	4.67 mils/ply

Figure 2-14. End View of Cured Part

Physical and Mechanical Properties 1 (IVF 1330) - The resin content across the chord of the panel was very uniform with an average of 24.17 Wt% which results in an average fiber volume of 68 percent. The resin content is lower than the 28.4 percent by weight that was achieved for the single hat panel 1. The mechanical properties were borderline in comparison to the specified values.

The same basic processing parameters of the hat panel 1 were used for this multihat panel 1. The exception was that the edge bleed strip was changed from 1-ply mochburg to 1-ply boat cloth. This change was made because the multihat panel was one-third wider, and it was felt that increased edge bleeding would occur. The boat cloth does absorb more resin than mochburg. A review of the bleeder system after cure did show considerable edge bleeding.

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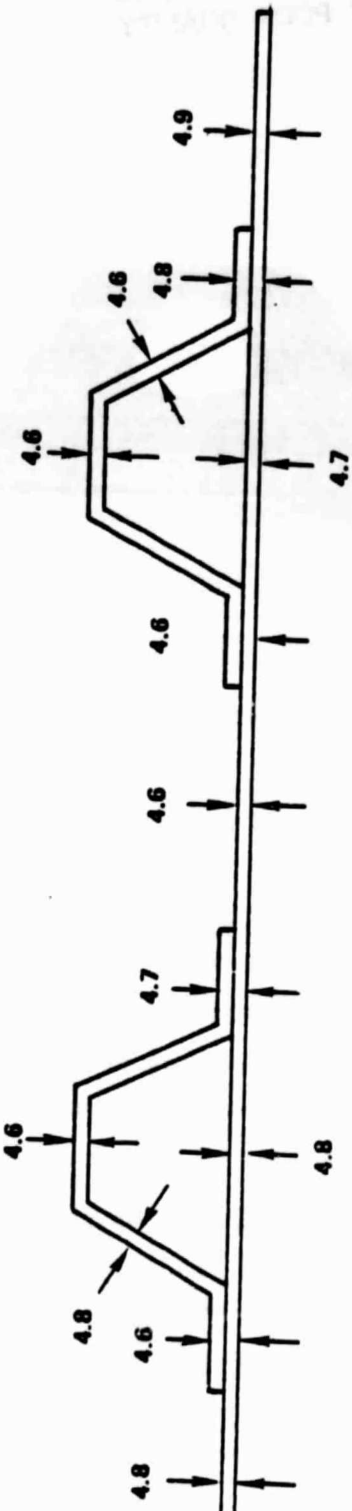

VALUES SHOWN ARE MILS/PLY AS AN AVERAGE TAKEN AT THE CENTER CUT SPECIMEN COUPON NO. 2 ALONG THE 39 INCH SPAN OF THE PANEL.

Figure 2-15. Dimensional Check, Multihat Stiffened Panel (IVL 1330) Specified PB 80-577 (4.6 to 5.3 Mils/Ply)

2.3.2 Process Development

2.3.2.1 Ribs

Truss Ribs - Truss rib development during the reporting period was directed toward optimizing the prebleed and cure cycles associated with the rib tooling. Due to the mass of these tools, the cure cycle of rib caps is very long, extending into a second shift.

A thermal profile of the truss rib tool was made while maximizing autoclave heatup rate, and also reducing the dwell time at 260 degrees. By this approach the cure cycle could be shortened to 5.5 hours.

A tool try specimens of the truss rib cap (No. 4) was laid up using the low resin content (34 percent) prepreg material utlized the shortened cure cycle. Evaluation and analysis of this part would indicate whether the combination of low-resin content material and modified cure cycle can be used in fabrication of ancillary test specimens. A depiction of the truss rib tool components is included as Figure 2-16.

The part looked good visually except for a slight concavity in the web opposite the bead stiffener. Some fiber wash was also noted. Dimensions were uniform in the web and flanges along the part, but were approximately 0.010 inch under nominal thickness. NDI C-scan on the web showed no discrepancies, but scans of the flanges indicated the surface condition, perhaps attributable to mold release, would not permit the ultrasonic energy to properly transverse the flanges. This is reported upon in the Quality Assurance Section of this report. Mode release is now being removed by detergent wash prior to NDI. The following conclusions were reached regarding this tool try part:

- The part planes of the tool will be shimmed 0.005 inch to increase part thickness from 0.0043 inch per ply obtained to the specification thickness of 0.0046 inch minimum per ply.
- All other factors to be maintained (cure cycle, prebled bead, etc.) constant.

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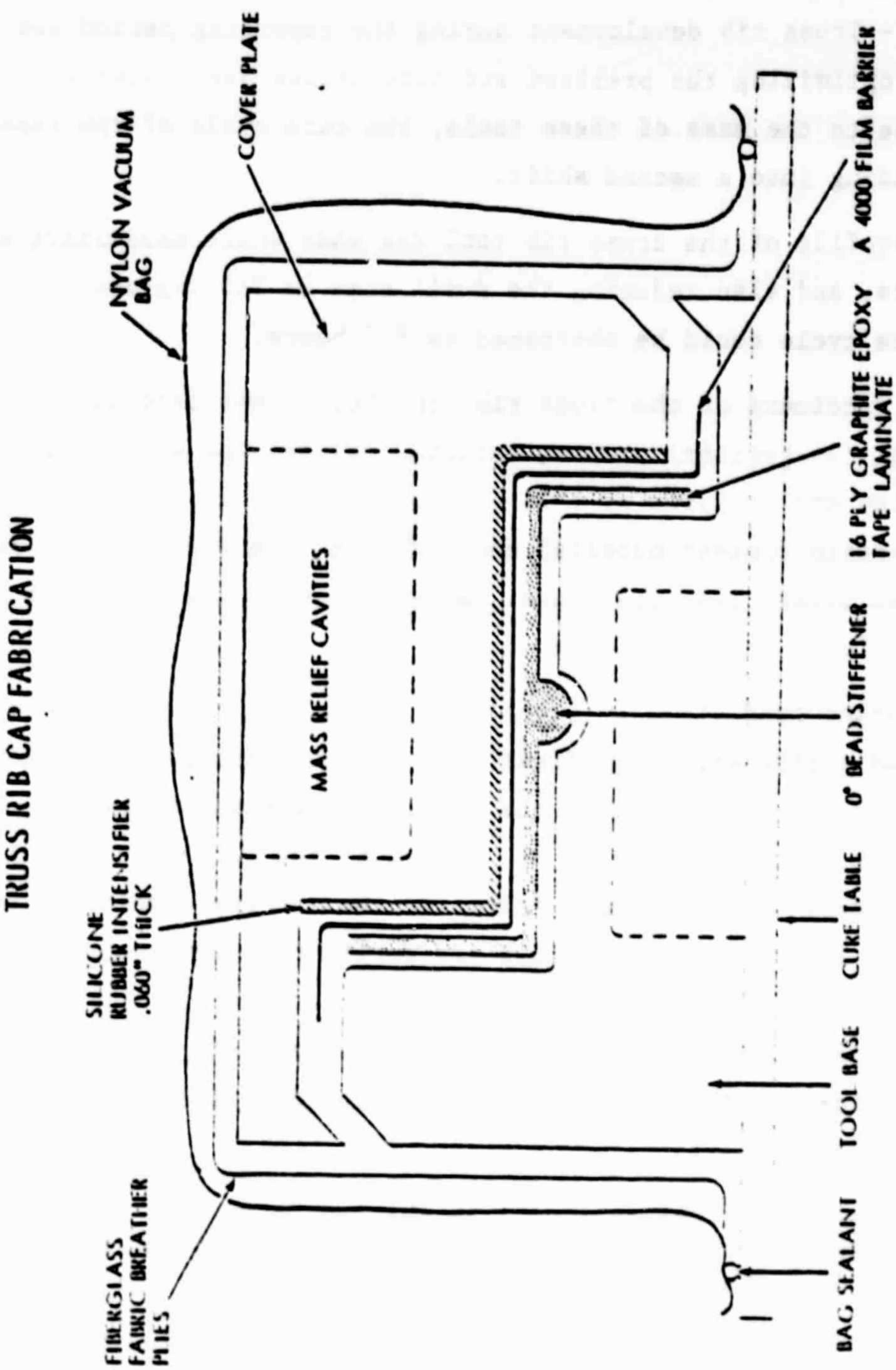

Figure 2-16. Truss Rib Cap Molding Components

- Fabricate next part to H20A (FAA conformity) shop order.
- Engineering to consider alternate 0 degree bead stiffener configurations which could be made on the 20 inch experimental tool.

Subsequently, a truss rib cap for H20A was laid up and cured. Dimensional inspection indicated that the tooling shim resulted in a part with acceptable dimensions. Ultrasonic indications were obtained in the web and flange areas. The cap was to be cut to length and photomicrographs from the excess as close to the cut as possible were made to assist in evaluating the acceptability of the part. Microphotographs of the bead indicate good bead fill. An integral tag end was tested to the requirements of PB 80-579. The results are given below:

Laboratory Number 350388

Specification Requirements		Results of Test: Top Flange	Web	Bottom Flange
Resin Content	26-30%	29.4	31.7	27.4
Specific Gravity	1.56-1.60	1.5784	1.5662	1.5876
Thickness Per Ply	0.0046-0.0053 in	0.0050	0.0051	0.0044
Short Beam Shear Strength at 180°F, Wet	6 ksi, min., indiv.	6.227	7,356	7,116
Compressive Strength at 180°F, Wet	75 ksi, min., indiv.	60,250	68,415	61,127

Engineering is evaluating these data and will determine if this part would be acceptable as a test part.

The other rib cap for H20A was laidup and cured. This part has been trimmed and is identified as 1608280-118. See Figure 2-17. Ultrasonic test indications were observed in the ends of this part. Thickness measurements of the part showed one flange somewhat below specification thickness. Thickness per ply was as low as 0.0041 inches compared to minimum of 0.0046 inches per ply. Resin content was also low. An integral tag end was tested to the requirements of PB 80-579. The results are given below:

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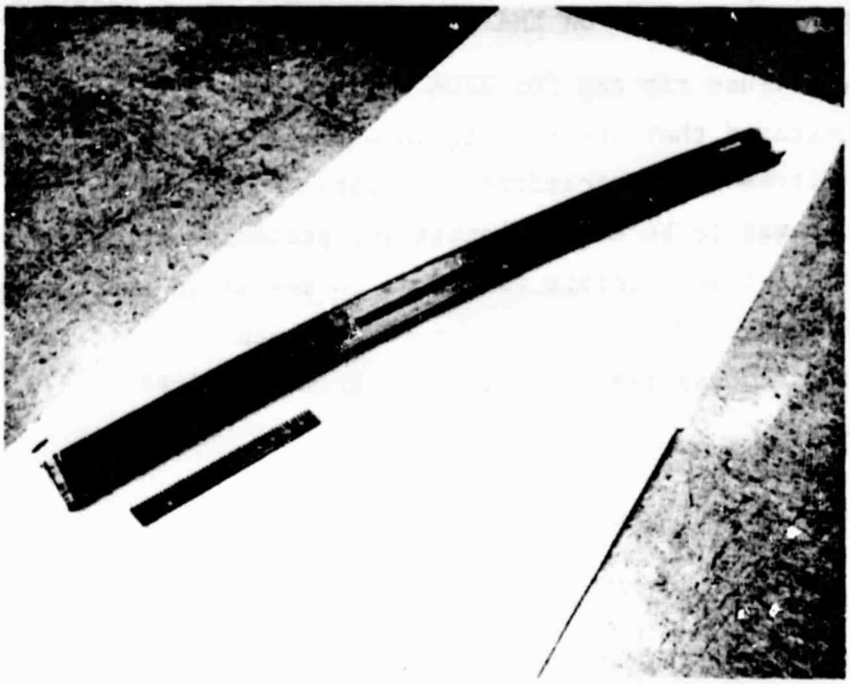

Figure 2-17. Truss Rib Cap, P/N 1608280-118 for H20A Specimen

Laboratory Number 350415

Specification Requirements		Top Flange	Web	Bottom Flange
		Results of Test		
Resin Content	26-30%	23.5	23.5	25.8
Specific Gravity	1.56-1.60	1.6082	1.6086	1.5923
Thickness Per Ply	0.0046-0.0053 in	0.0041	0.0048	0.0045
Short Bean Shear Strength at 180°F, Wet	6 ksi, min., indiv.	6,429 6,822	8,100	8,555
Compressive Strength at 180°F, Wet	75 ksi, min.,	58,182	68,305	63,889

The reason for the low-resin content is not known. Processing data is being reviewed. Layup and tooling arrangement were identical to the previous part which had resin content in the acceptable range.

Actuator Rib - For a third actuator rib cap tool proving part was molded, the eight-ply outer layer cap flange segment and the 0 degree bead stiffener only were prebled and combined in the tool with the 2 eight-ply halves of the rib. Dimensional check of this cured laminate revealed a thickening in the web in the center of the part of approximately 0.030 inch tapering to nominal dimensions at both ends of the 96 inch specimen. This condition is believed to have been caused by excess resin trapped within the tool. Use of low-resin content prepreg could resolve the condition. An illustration of the tooling setup for actuator rib cap fabrication is included in Figure 2-18.

Because of the over tolerance web thickness of actuator rib cap tool try part (No. 3) the tool was reinspected by Tool Inspection. A plastic sample part was cast in the tool and measured. Although no autoclave pressure was available to seat the tool segments, it was still considered a reasonably accurate check. Although some of the reading in the web area thus obtained were slightly over tooling tolerance (maximum differential 0.023 inch vs ±0.010 inch), the central bow previously reported and believed caused by trapped resin in tool try part (No. 3) was not in evidence.

Tool Try Part (No. 4) laid up with 34 percent resin content prepreg was cured on 8-18-78. This part had poor definition and extensive delamination that were the result of inadequate molding pressure due to the tool components not seating. Alternate tooling concept and/or modifications to the tooling shown in Figure 2-18 were considered, and it was decided to modify the existing tool by adding details which will prevent the tool components from cocking relative to each other when closing under autoclave pressure. In addition, a new rubber strip is being bonded to the flange face to replace the previous loose piece which was difficult to put in place during layup. These alterations were completed this month and the next actuator rib cap tool try part is now in layup.

Solid Web Rib - Modifications to the solid web tooling were completed to move the rubber sheeting from the female side of the tool to the opposite side as shown in Figure 2-19. This change was made to facilitate layup of the six-ply rib segment into the female tool half for prebleeding. A fiberglass

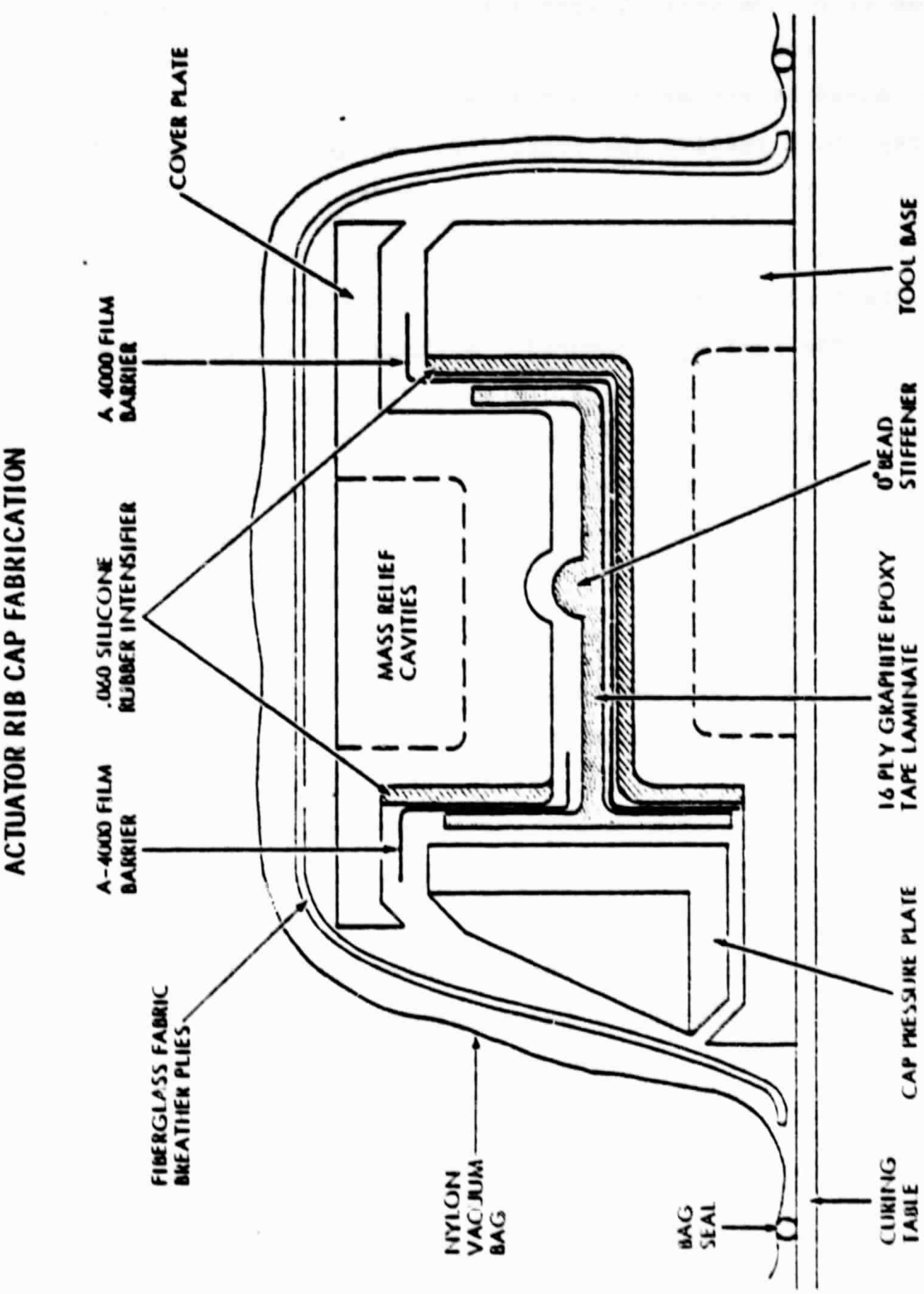

Figure 2-18. Actuator Rib Cap Molding Components

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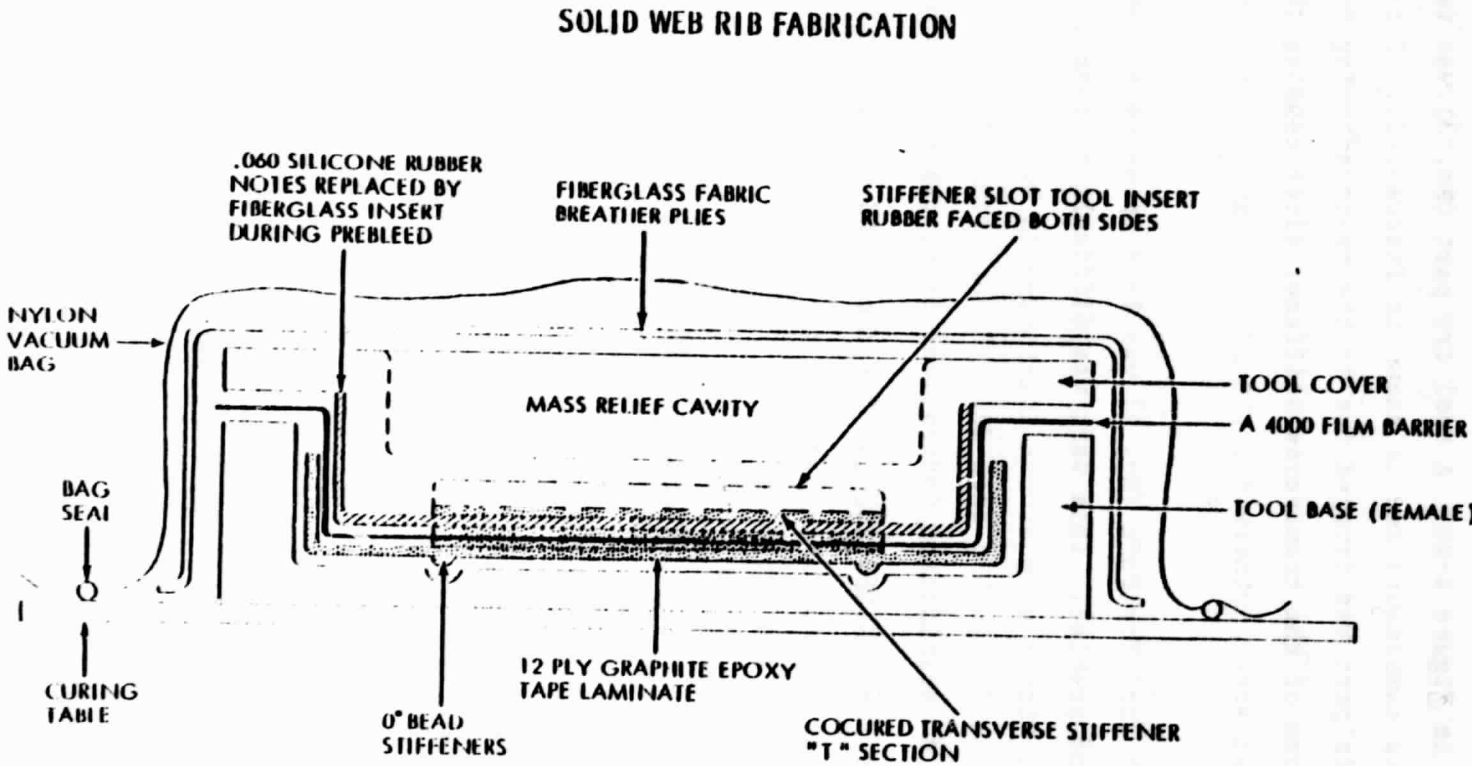

Figure 2-19. Solid Web Rib Molding Components

overlay was fabricated to replace the rubber over the male tool half during prebleed as shown in Figure 2-20. A tool try part (No. 3) was fabricated with the revised tooling components and is shown in Figure 2-21. During removal from the tool, this part was damaged due to the resin adhering to the silicone rubber facing in one of the transverse stiffener slots causing the delamination of the part in that area. Otherwise, the part had good definition and no NDI indications.

Solid Web Rib Tool Try Part (No. 4) was laid up using 41 percent resin content prepreg and prebled. This part was difficult to remove from the female tool half. It was within dimensional tolerances in both the 12-ply and 14-ply areas. However, one flange had been damaged upon removal from the tool. The NDI C-scan showed no significant indications of porosity or voids.

The solid web rib P/N 1608281-103 for the H24AS specimen has been molded and is acceptable to engineering. See Figure 2-22. An integral tag end was tested and the results are given below:

Laboratory Number 350300

		Results of Test		
Specification Requirements		Cap No. 1	Cap No. 2	Web
Resin Content (%)		28.8%	27.4%	27.5%
				26.1%
Specific Gravity		1.59	1.60	1.60
				1.60
Compressive Strength (psi)	at R.T.	71,629	63,746	--
	at 180°F Wet	59,610	52,147	25,938
				33,438

The rib, prior to machining the hat cutouts is shown in Figure 2-22.

Rib Development - An investigation is continuing to improve bead definition in the rib caps. Using a 20-inch long tool, representative of the truss rib cap tool, a part was molded using a formed rubber blanket to define the bead

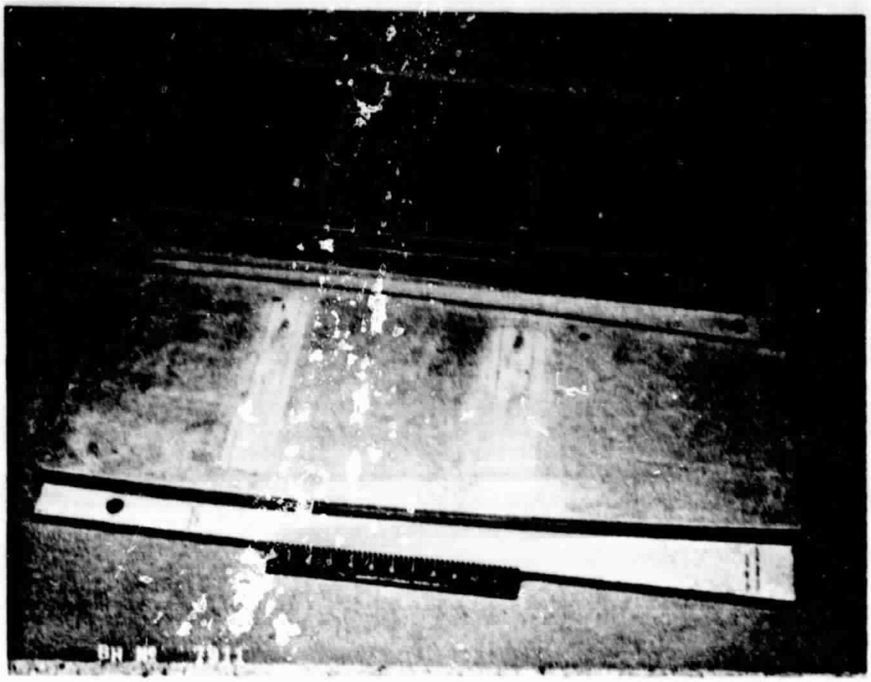

Figure 2-20. Solid Web Rib Ancillary Specimen Tool Half with Fiberglass Insert for Prebleeding

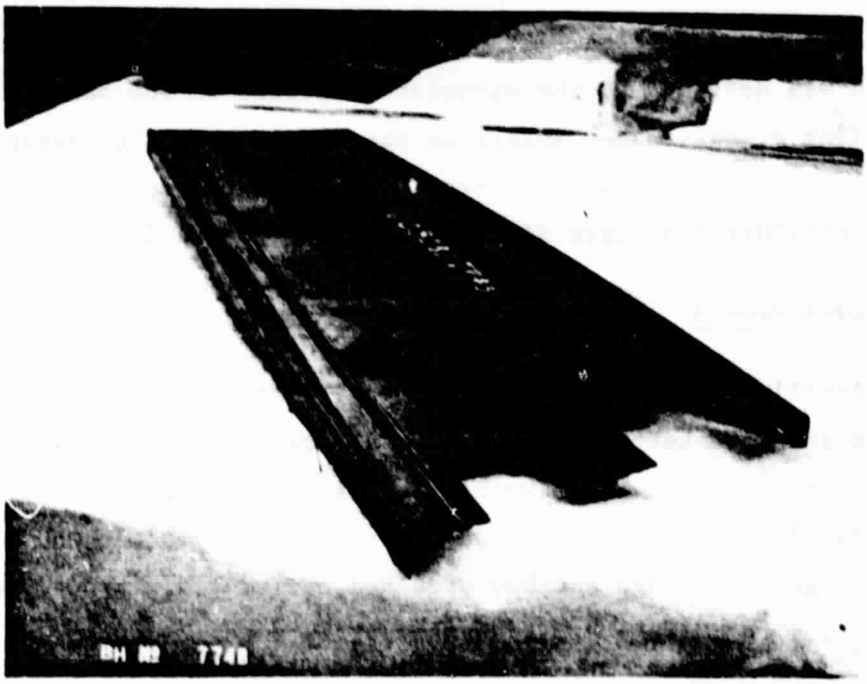

Figure 2-21. Solid Web Rib Tool Try Part

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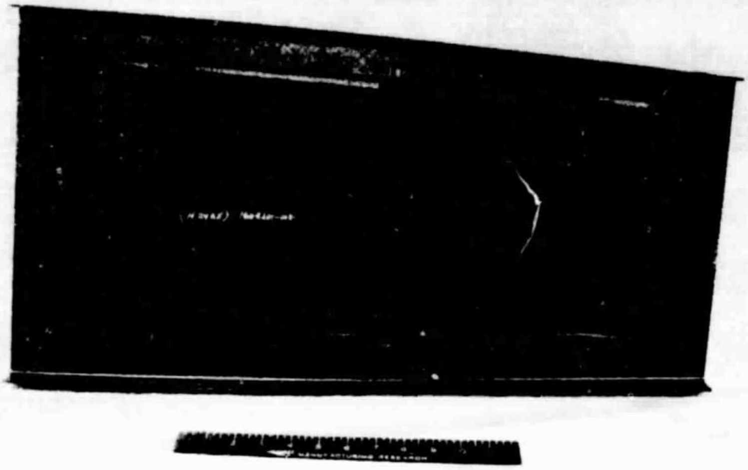

Figure 2-22. Solid Web Rib P/N 1608281-103
for H24AS Specimen

in lieu of the aluminum tool half. See Figure 2-23. This was unsatisfactory as the bead was deformed by the autoclave pressure on the bag. A second part was made using a cast rubber insert in the aluminum tool to define the bead. While the resulting part had good bead definition the opposite side of the web showed considerable fiber dislocation. See Figure 2-24.

2.3.2.2 Cover Panels

H-28 Ancillary Specimen - One H-28 ancilliary specimen consiting of a 16-ply skin and five hat stiffeners was fabricated. The 16-ply skin was prebled in a single cycle. The five hat stiffeners were prebled by prebleeding the 10 plies of 0 degree orientation first, then assembling the remaining 10 plies and going through another prebleed cycle. This procedure has been common practice for all hat-stiffeners fabricated to date.

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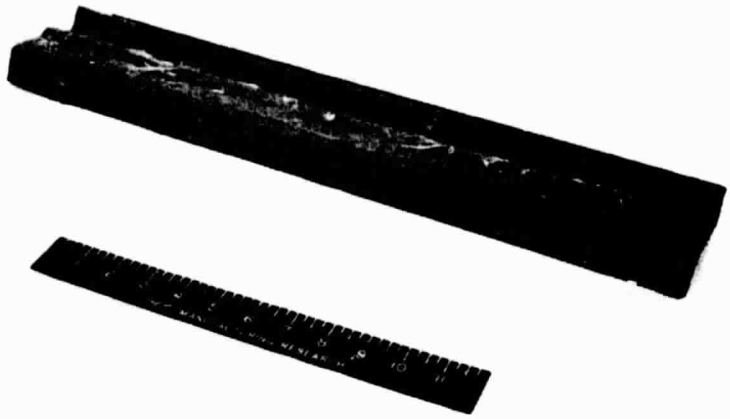

Figure 2-23. Formed Rubber Blanket Used to Define Bead

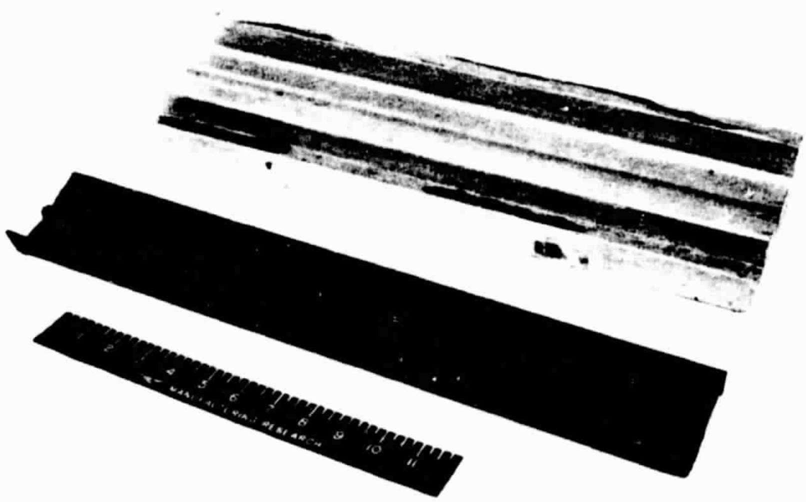

Figure 2-24. Rubber Bead Insert in Aluminum Tool

Visual examination of the hats and skin after prebleed was made and tracings were made to show specific location of all wrinkles for future reference.

Dimensional analysis of the cured assembly indicated that the assembly was within drawing requirements except for flatness or contour. Maximum bow occurred at midspan along the hat-stiffeners and measured approximately 0.625 inches.

Warpage of the assembly is attributed to the effect of the wire fabric lightning strike protection on the outer surface of the skin. Other factors might have some effect on the assembly flatness, however, the wire fabric has been isolated as the primary problem area. The wire fabric will be omitted on the replacement H-28 ancillary.

NDI C-Scan showed indications of discrepant conditions in the hat flange to skin joints of two of the hat stiffeners. The remaining three hats were free of any discrepant conditions. A review of the cure cycle records, particularly during pressure leak check at 260°F and 85 psi, revealed a positive pressure leak of 1.5 pounds and holding steady for 10 minutes. This leakage was not considered significant and the cure cycle was completed. In the final analysis, the assembly was not considered satisfactory and a replacement H-28 ancillary specimen is being fabricated.

To minimize the possibility of the slightest leakage on future parts, all autoclave lines and connections are being checked and replaced as required. Vacuum connections in the MBF's are also being checked and replaced as required.

Test pieces were cut from each of the five hat stiffeners for the purpose of comparing joint strength of the questionable hats to the hats which were free of ultrasonic indications. The results of the test are tabulated below:

Hat No.	Ultrasonic Scan	Hat Pullout Load-Lbs	Failure Mode
1	Good	252	Ideal
2	Good	250	Ideal
3	Good	233.5	Ideal
4	Questionable	218.0	Ideal
5	Questionable	250.5	Ideal

Hat stiffener No. 4 appears to be slightly below expected but, possibly, still within the range of acceptability. Although the limits of acceptability for hat pullout have not been established the results obtained are comparable to highs obtained in previous tests.

The failure mode in all hats is identified as ideal since failure did not occur as a clean separation along the flange to skin interface. Portions of adjacent plies pulled away as failure occurred. Joint failures of this nature are very close to optimum. Joints which fail as a clean separation along the interface are typical of low strength joints. The remains of this panel are being retained for possible future use to gather additional test data.

The replacement H-28 ancilliary panel is currently being fabricated and will incorporate improvements made in hat stiffener prebleeding technique. Past practice consisted of prebleeding the 10 plies of 0 degree orientation in one cycle and then assemblying the remaining 10 plies and going through a second prebleed cycle. In this assembly, the 10 plies of 0 degree orientation and the remaining 10 plies were all preplied together as one layup and exposed to only only prebleed cycle. Steel caul plates (not previously used) were placed over the 20 ply area of the hats to eliminate crowning in this area during prebleed. This crowning effect is undesirable since the material buildup is believed to be forced downward during final cure. The end result is a bulge or crowning effect in the opposite direction.

There was no evidence of crowning in the hat stiffeners prebled in a single cycle. It is also anticipated that the bulge or crown effect previously noted in final cure will be eliminated.

H-25 Ancilliary Panel - The first H-25 ancilliary panel has been cured and ultrasonic scanning has been completed. All ultrasonic indications were reviewed by Engineering and the panel was dispositioned as acceptable for use.

Quality Assurance Verfication Tests are in progress and physical and mechanical property data will be reported when tests have been completed and reviewed. The hat stiffeners for this panel were the first to use the single stage prebleeding techniques. Single cycle prebleeding is planned for all future panels.

H-27 Ancilliary Panel - Ultrasonic scanning of the completed panel revealed indications in the hat stiffener crown area. This condition was deemed unacceptable to Engineering and the panel was dispositioned as acceptable for use as an H-12A ancilliary.

The ultrasonic indications in the crown areas have not been fully identified as to effect on structural integrity. Additional evaluations by the ultrasonic laboratory are being conducted to explore these conditions in greater depth.

Graphite Caul Plate Investigation - An attempt was made to eliminate wrinkles in skins during prebleed by using a graphite epoxy caul plate between the layup tool surface and a 16-ply graphite epoxy skin layup.

The stacking sequence used in this investigation consisted of the following:

1. One ply of bleeder cloth on the tool surface.
2. Graphite epoxy caul plate.
3. One ply nonperforated barrier film.
4. One ply of armalon
5. One ply of nylon taffeta peel ply material
6. A typical 16-ply graphite epoxy skin layup
7. One ply of armalon
8. Two plies of bleeder material

The layup was vacuum bagged and prebled per P.B. 80-577 prebleed cycle. Photographs (Figure 2-25) taken after prebleed show the extent of wrinkling. A tracing of the wrinkle patterns and locations was made and is being retained for future reference. No additional investigation of skin wrinkling is in progress. The skin panel used in this investigation is being used in the replacement H-28 ancilliary currently in fabrication.

Inflatable Bladders - Bladder design is being changed to increase the wall thickness from 0.060 to 0.120 minimum. Although bladder removal has not been a problem, it is anticipated that this change will reduce frequency of bladder damage and repair and extend the bladder life span.

Pressure testing procedures have been established to check for leaks or damage before each use. Procedures for repair and subsequent testing have also been established.

All bladders used to date have been molded in female mold fixuters. Fabrication of full scale bladders in this manner has created some concern. Consequently, an investigation is in progress to determine the feasibility of using extruded bladders.

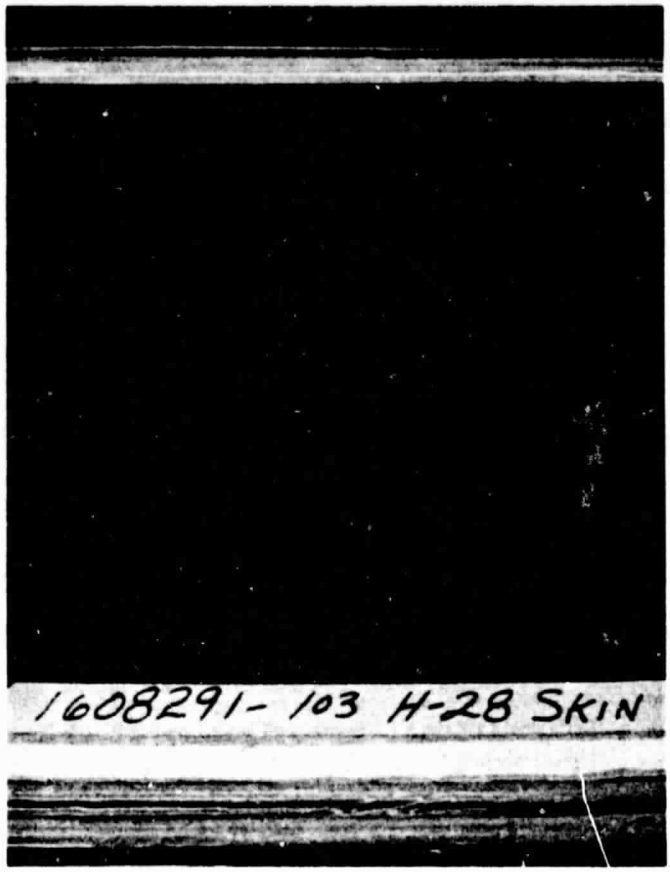

Figure 2-25. Wrinkling of Laminate Prebled on Graphite Caul Plate

2.4 QUALITY ASSURANCE

2.4.1 Laboratory Tests

The Quality Assurance Laboratory performed two basic functions during the reporting period: (1) Batch testing to ensure that the graphite/epoxy material is acceptable prior to its use, and (2) testing of parts fabricated for either the process development studies or the Engineering Ancillary Test Program.

2.4.1.1 Acceptance Tests

The Quality Assurance Laboratory tested and accepted T300/5208 material, batch number 1220. Test results are shown in Table 2-5.

Batch number 1154, a low-resin content T300/5208 material was acceptance tested for Engineering evaluation and possible application on the ACVF Program. In conjunction with this effort, the laboratory developed a method to produce the desired 29 percent resin content (cured) panels from the low-resin content 31 percent to 37 percent material. Success was reached by eliminating the peel ply and slits in the film over the caul plate.

2.4.1.2 Process Development Tests

The Quality Assurance Laboratory continued to support the single-stage process development program and the rib process development program. Twelve hat/skin assemblies, six flat panels and six rib caps were tested per requests from Manufacturing Research and Engineering. Specific tests include compressive strength, short beam shear, hardness, resin content, and specific gravity. In addition, 32 prebled uncured details were tested for resin content, shore D hardness, and specific gravity. Hat/skin sections which had been made by different methods were pulled apart in the testing machine to establish ultimate strength and load-deflection curves. Numerous photomicrographs were taken of the hat/skin assemblies, ribs and panels for correlation with NDI.

TABLE 2-5. T300/5208 BATCH ACCEPTANCE TEST RESULTS

C22-1378 A /111 SPECIFICATION REQUIREMENTS		RESULTS OF TEST 1	2	3	4	5	AVG
AREAL WT (4) (3" X 3")	139-149 GMS/METER^2	141	144	145	142		143
INFRARED SPECTROPHOTOMETRIC ANALYSIS (1)		Conforms					
VOLATILES (2) (60 ± 5 MINUTES AT 350°F)	3% MAX EDGE	1.89					
	CENTER	2.00					
DRY RESIN CONTENT (4) (3 X 3")	38-44%	38.4	39.7	39.1	38.6		39.0
FLOW (2) AT 350°F AT 85 PSI	15-29%	18.0	17.6				
GEL TIME (2) AT 350°F	INFO ONLY, MINUTES	21.6	20.9				
CURED FIBER VOLUME (3) 0.080 IN. PANEL	60-68%	66.5	66.6	66.8			66.6
CURED FIBER VOLUME (3) 0.040 IN. PANEL	60-68%	67.8	67.6	67.8			67.7
SPECIFIC GRAVITY (3) 0.080 IN. PANEL	1.55-1.62	1.584	1.581	1.585			1.583
SPECIFIC GRAVITY (3) 0.040 IN. PANEL	1.55-1.62	1.600	1.598	1.597			1.598
TENSILE STRENGTH, LONGITUDINAL (3) AT 75°F	170 KSI, MIN, IND	247	241	227			238
TENSILE MODULUS, LONGITUDINAL (3) AT 75°F	20 X 10^6 PSI, MIN, IND	23.1	22.6	22.8			22.8
FLEXURAL STRENGTH (3) AT 75°F	210 KSI, MIN, IND	282	272	289			281
FLEXURAL MODULUS (3) AT 75°F	18 X 10^6 PSI, MIN, IND	19.1	19.1	19.5			19.2
FLEXURAL STRENGTH (3) AT 180°F	200 KSI, MIN, IND	237	252	248			246
FLEXURAL MODULUS (3) AT 180°F	16 X 10^6 PSI, MIN, IND	19.1	18.7	20.0			19.3
SHORT BEAM SHEAR (3) AT 75°F	13 KSI, MIN, IND	17.2	19.8	18.7			18.6
SHORT BEAM SHEAR (3) AT 180°F	12 KSI, MIN, IND	15.7	16.0	15.4			15.7
THICKNESS PER PLY (5) 0.080 IN. PANEL	.0046-.0056 IN.	.0048	.0048	.0048	.0047	.0047	.0048
THICKNESS PER PLY (5) 0.040 IN. PANEL	.0046-.0056 IN.	.0046	.0048	.0046	.0047	.0046	.0047

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NOTES: BATCH 1220
DATE 8-16-78
LAB REPORT 349560

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2.4.2 Inspection Activities

Inspection and the FAA DMIR witnessed or monitored layup of the Engineering Ancillary Test items.

The following Inspection Tags were written during the reporting period:

Inspection Tag Number	Part Number	Description	Primary Cause
F 147725	1608281-103	Rib Cap	• Delamination • Concave bead
F 199020	1608282	Rib Cap	• Delaminations
F 084367	1608291-101	Panel	• Wrinkles • Warped panel
F 084356	1608280-118	Rib Cap	• Ultrasonic indications • Concave bead
F 214974	1608280-104	Rib Cap	• Bridge in radius • Resin rich areas
F 084362	1608282-103	Rib Cap	• Ultrasonic indications
F 214968	1606607-901	Hat Filler	• Wrinkles
F 147720	1606607-901	Hat Filler	• Procedure did not conform to process bulletin

2.4.2.1 Nondestructive Inspection (NDI)

During this reporting period activity has occurred in the following areas:

- Support of process development.
- Development of cost-effective NDI procedures.

Support of Process Development - Activity has been directed toward support of manufacturing efforts. Table 2-6 summarizes the parts submitted for ultrasonic inspection.

One 100-inch long flat panel, serial number WR No. 1 was submitted for ultrasonic inspection. Although this panel had some visual wrinkles after prebleed the ultrasonic indications were minimal after cure, as shown in Figure 2-26.

Three 18-inch by 22-inch flat panels, fabricated from low-resin content material, were ultrasonic inspected. No indications were noted on these panels. Serial numbers are 2VF 1307, 3VF 1307, and 4VF 1307.

The 12-inch by 40-inch hat-stiffened panel, serial number 1VF 1314, was ultrasonic inspected in the hat flange and skin joint areas. No indications are evident in those areas. See Figure 2-27.

At the request of Manufacturing and Engineering, a second ultrasonic inspection was performed on P/N 1608280-TP No. 4 Truss Rib. Initial inspection results had shown solid indications in the flanges as shown in Figure 2-28. Several factors were found as causes of the solid indications, however, the principal reason was parting agent residue on the part surfaces. The part was cleaned and a second ultrasonic inspection revealed a significant improvement in the flange areas, however, sufficient indications remain for an unacceptable condition per current specification criteria (see Figure 2-29). Figure 2-30 shows a C-Scan of an unacceptable hat-stiffened panel, and Figure 2-31 shows a C-Scan of an acceptable hat-stiffened panel. Planning has incorporated a cleaning operation on shop orders prior to ultrasonic inspection for future parts to be fabricated.

Development of Cost Effective Procedures - An evaluation of NDI techniques applicable to thickness measurement of graphite epoxy composite laminates has begun. A limited industry survey indicates that pulse-echo ultrasonics is the most commonly used method. Various commercial instruments which accomplish the same goal are utilized by companies surveyed that use pulse-echo ultrasonics. Specifically, these instruments measure transit time

TABLE 2-6. NDI SUPPORT OF DEVELOPMENT PROGRAM

Part or Serial No.	Name or Description	Figure No.
2VF 1307	Flat Panel (18 x 22)	
3VF 1307	Flat Panel (18 x 22)	
4VF 1307	Flat Panel (18 x 22)	
WR #1	Flat Panel (22 x 100)	2-1
1VF 1314	One Hat Cover (12 x 40)	2-2
1608280-TP #3	Truss Rib	
1608281-103	Solid Web Rib	
1608282-103	Actuator Rib	
1608280-TP #4	Truss Rib	2-3/2-4
1608280-117, TP #5	Truss Rib	
1608281-TP #4	Solid Web Rib	
1VF1326	One Hat Cover (12 x 36)	2-6
1VL1330	Two Hat Cover (16 x 25)	2-5
1A	Flat Panel - 10 Ply (18 x 32)	
2A	Flat Panel - 10 Ply (18 x 32)	
1B	Flat Panel - 16 Ply (18 x 32)	
2B	Flat Panel - 16 Ply (18 x 32)	
1C	Flat Panel - 34 Ply (18 x 32)	
2C	Flat Panel - 16 Ply (18 x 32)	
1D	Flat Panel - 34 Ply (18 x 32)	
2D	Flat Panel - 16 Ply (18 x 32)	
E	Flat Panel - 16 Ply (18 x 32)	
2E	Flat Panel - 34 Ply (18 x 32)	
F	Flat Panel - 32 Ply (18 x 32)	
2F	Flat Panel - 34 Ply (18 x 32)	
2G	Flat Panel - 34 Ply (18 x 32)	
#1 Control	Flat Panel - 14x14 Ply (18 x 32)	
#2 Control	Flat Panel - 14x14 Ply (18 x 32)	
1608280-TP #6	Truss Rib	
1608281-103	Solid Web Rib	
1608291-107	H-28 Cover Specimen	

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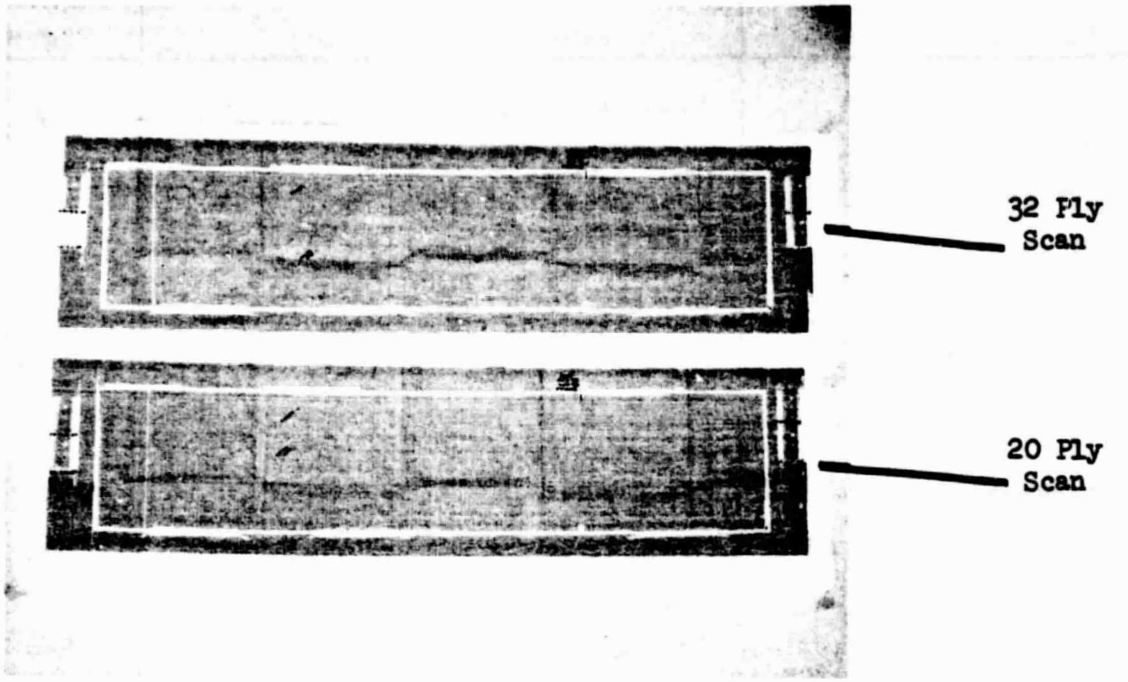

Figure 2-26. Reflected Through Transmission C-Scan of Panel WR No. 1

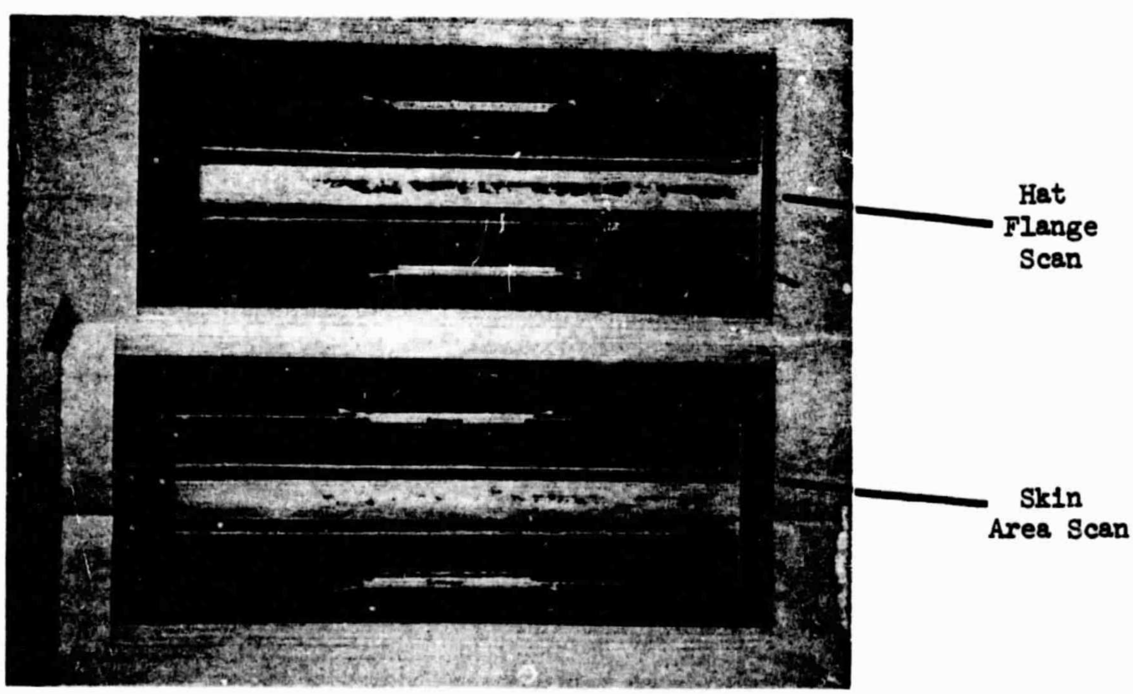

Figure 2-27. Reflected Through Transmission C-Scan of Panel 1VF 1314

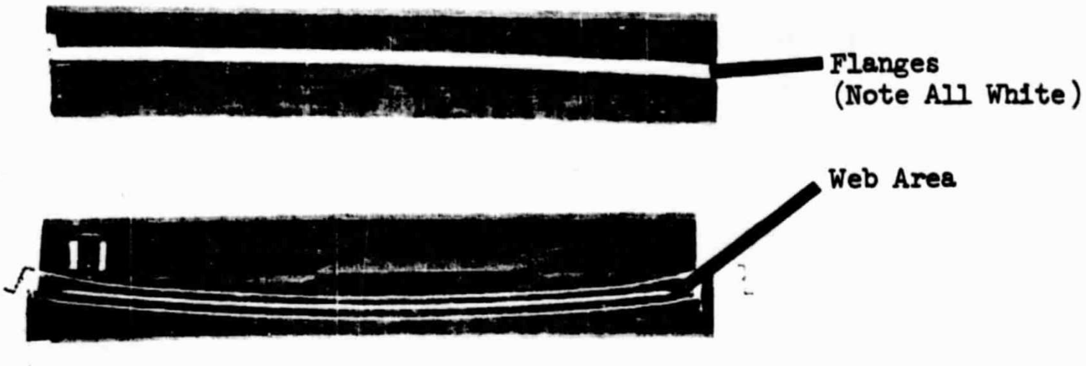

Figure 2-28. Original Reflected Through-Transmission C-Scans of P/N 1608280-TP No. 4

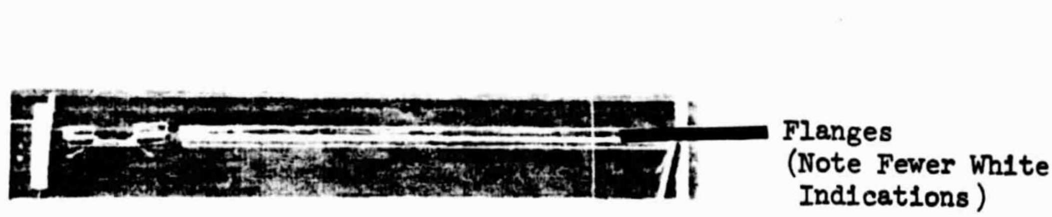

Figure 2-29. Reflected Through-Transmission C-Scan of a Section of P/N 1608280-TP No. 4 (Flange Only)

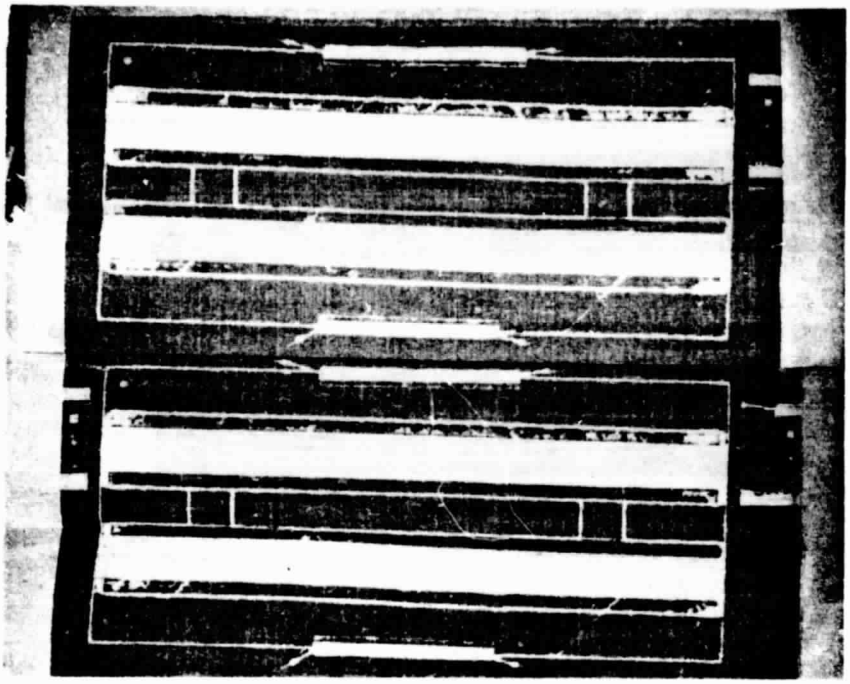

Figure 2-30. Reflected Through-Transmission C-Scan of Hat-Stiffened Panel IVL 1330

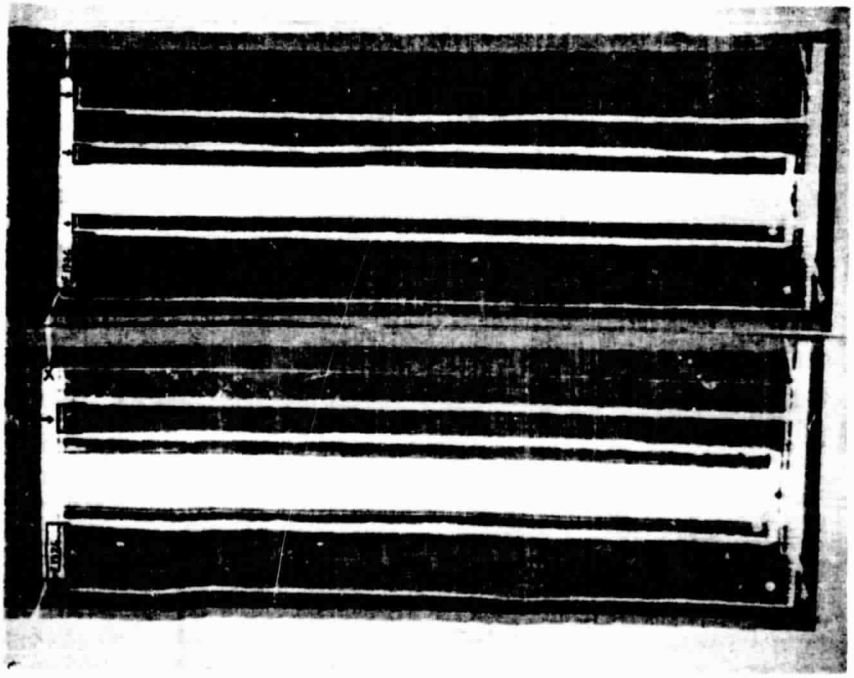

Figure 2-31. Reflected Through-Transmission C-Scan of Hat-Stiffened Panel IVF 1326

within the laminate and by assigning a velocity through calibration provide a digital display of thickness. The problem encountered is nonuniform signal velocity within graphite epoxy laminates. Cause and extent of these nonuniformities are not completely understood. These variations in velocity directly affect the readings obtained with this type of instrument.

SECTION 3

PHASE II - DESIGN AND ANALYSIS - SPARS

Phase II design and analysis of the spars, comprises the main engineering effort of Lockheed-Georgia Company in the design, development, and fabrication of the front and rear spars for the L-1011 advanced composite vertical fin. The engineering effort during this reporting period covered four tasks: component definition, process verification, concept verification, and quality assurance.

3.1 COMPONENT DEFINITION

Component definition covers the detail design and structural analysis of the selected front and rear spar configurations.

3.1.1 Detail Design

The detail design of the ACUF spars has been completed.

3.1.2 Structural Analysis

Stress analysis of the L-1011 ACVF spars was completed and checked. Margins of safety were generally higher in the rear spar web than in the front spar as verified by the H23A front spar tests. Figure 3-1 shows the planform geometry of the front and rear spars and identifies the panels and ply orientations used in the stress analysis. Figure 3-2 shows the spar cap axial loads and the spar web shear flows. Table 3-1 lists the T300/5208 properties and allowables used in the analyses, and Tables 3-2 and 3-3 summarize the spar webs margins of safety.

As an example, Table 3-2 shows panel 1 at VSS 100.2 has a margin of safety of +0.05 in the cut-out and +0.11 in buckling. The allowable shear buckling strength was computed to be 1795 pounds per inch and the resultant M.S. shown

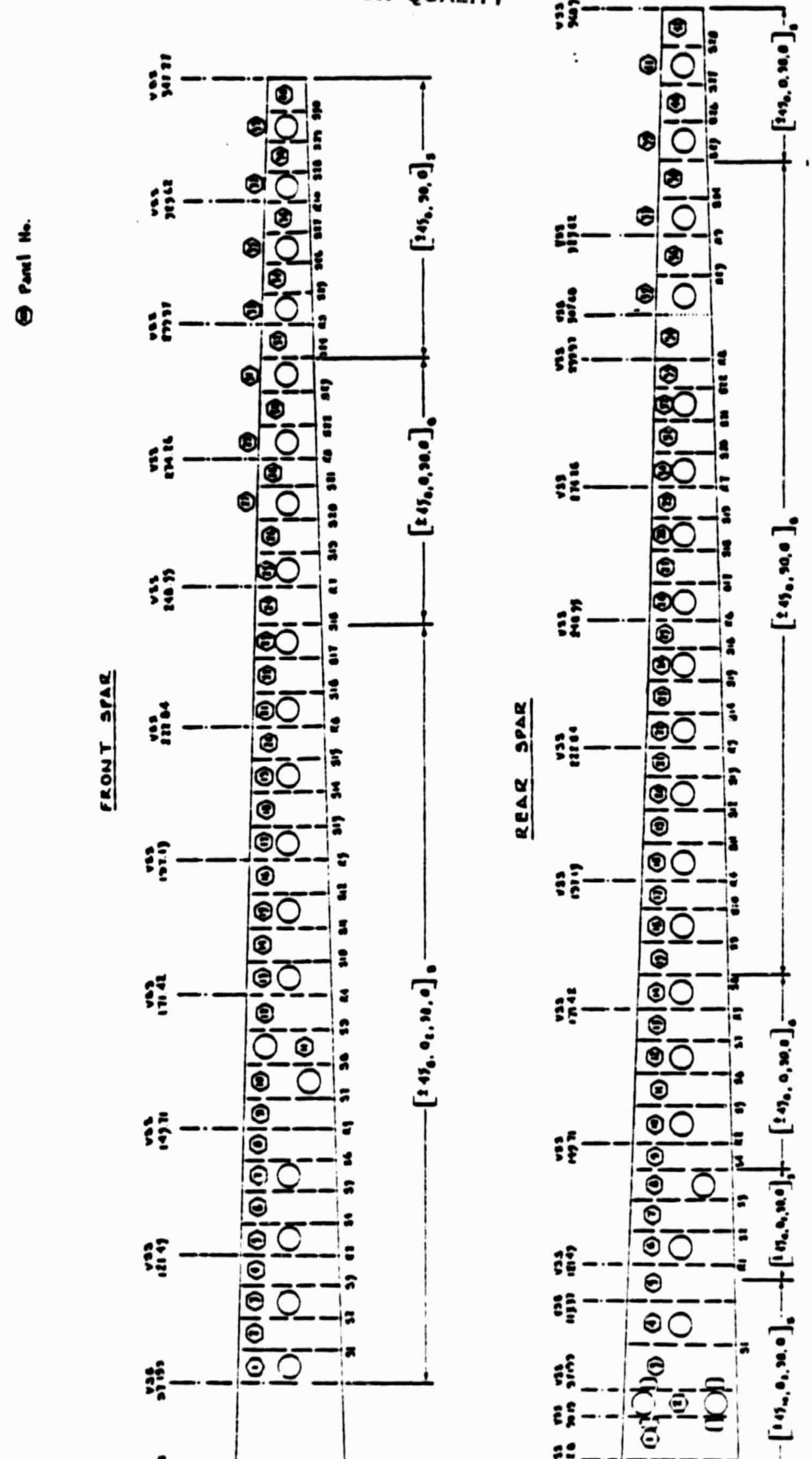

Figure 3-1. Planform Geometry of Front and Rear Spars

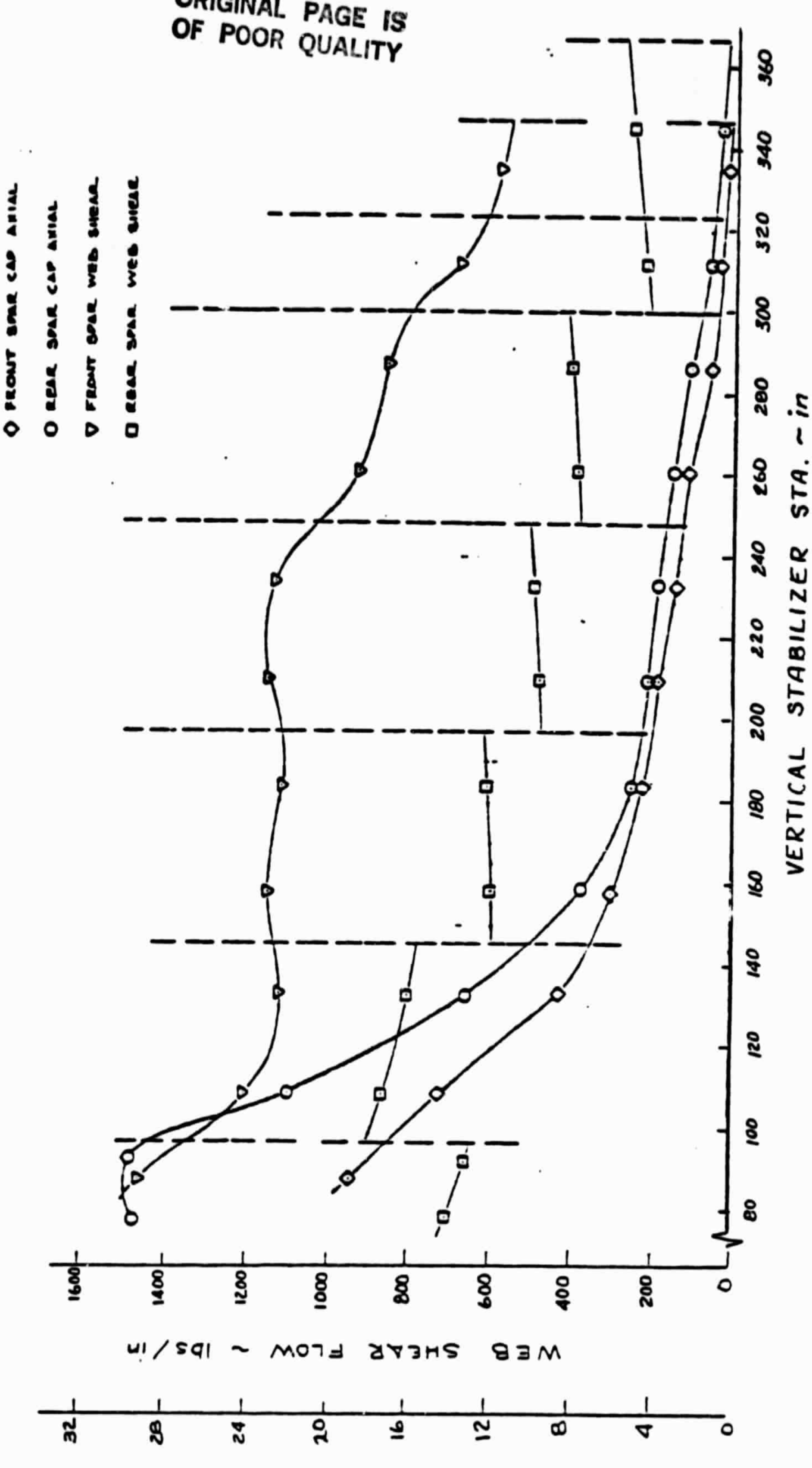

Figure 3-2. Ultimate Spar Cap Axial Loads and Web Shear Flows

TABLE 3-1. PROPERTIES AND ALLOWABLES
OF T300/5208 USED IN ANALYSIS

PROPERTIES		RTD	180 Wet	-65 Dry	Units
E_{11} Tension		20.0E6	20.3E6	19.5E6	psi
E_{11} Compression	=	19.0E6	18.0E6	19.5E6	psi
E_{22} Tension	=	1.60E6	1.40E6	1.78E6	psi
E_{22} Compression	=	1.56E6	1.36E6	1.75E6	psi
G_{12} Shear	=	0.80E6	0.60E6	0.86E6	psi
μ_{12} Maj Poisson's	=	0.27	0.26	0.28	-
α_1 L Coef of Exp	=	0.24E-6	0.28E-6	0.20E-6	in/in/°F
α_2 T Coef of Exp	=	16.2E-6	18.8E-6	15.1E-6	in/in/°F
ρ Density	=	0.058	0.058	0.058	lbs/in^3

ALLOWABLE LIMIT STRAINS, μ micro inches/inch

0° Tension	=	6000	6000	6000
0° Compression	=	5400	5000	4000
90° Tension	=	5000	4667	4667
90° Compression	=	8000	8000	8000
Shear	=	10000	10000	8600

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TABLE 3-2. SUMMARY OF FRONT SPAR WEB MARGINS (Sheet 1 of 2)

Panel	V.S.S. in.	q lbs/in	q_{net} lbs/in	b in.	a in.	Config. ±45/0/90	q_{cr} lbs/in	M.S. (Buckling)	M.S. (Cutout)
--	97.2	--	--	--	--	--	--	--	--
1	100.2	1290	1613	6.3	20.0	16/6/2	1795	+0.11	+0.05
2	106.3	1235	1235	"	19.7	"	1802	+0.46	--
3	112.4	1200	1512	"	19.4	"	1809	+0.20	+0.12
4	118.4	1172	1172	"	19.1	"	1816	+0.55	--
--	121.45	--	--	--	--	--	--	--	--
5	121.4	1150	1461	6.2	18.8	16/6/2	1875	+0.28	+0.16
6	130.4	1138	1138	"	18.5	"	1884	+0.66	--
7	136.4	1135	1455	"	18.2	"	1893	+0.30	-0.17
8	142.1	1145	1145	6.0	17.9	"	2012	+0.76	--
--	145.71	--	--	--	--	--	--	--	--
9	148.5	1155	1155	5.9	17.6	16/6/2	2080	+0.80	--
10	155.1	1160	1509	6.8	17.3	"	1632	+0.08	+0.13
11	161.6	1148	1504	"	16.9	"	1641	+0.09	+0.13
12	168.2	1133	1133	"	16.6	"	1648	+0.45	--
--	171.42	--	--	--	--	--	--	--	--
13	174.6	1125	1491	6.6	16.3	16/6/2	1745	+0.17	-0.14
14	180.9	1120	1120	"	16.0	"	1753	+0.57	--
15	187.3	1125	1510	"	15.7	"	1761	+0.17	+0.12
16	193.6	1138	1138	"	15.3	"	1773	+0.56	--
--	197.13	--	--	--	--	--	--	--	--
17	200.3	1145	1561	6.6	15.0	16/6/2	1783	+0.14	+0.09
18	206.7	1150	1150	"	14.7	"	1794	+0.56	--
19	213.0	1155	1599	"	14.4	"	1805	+0.13	+0.06
20	219.4	1155	1155	"	14.1	"	1817	+0.57	--
--	222.84	--	--	--	--	--	--	--	--

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TABLE 3-2. SUMMARY OF FRONT SPAR WEB MARGINS (Sheet 2 of 2)

Panel	V.S.S. in.	q lbs/in	q_{net} lbs/in	b in.	a in.	Config. ±45/0/90	q_{cr} lbs/in	M.S. (Buckling)	M.S. (Cutout)
--	222.84	--	--	--	--	--	--	--	--
21	226.0	1152	1622	6.6	13.8	16/6/2	1830	+0.13	+0.05
22	232.4	1144	1144	"	13.4	"	1849	+0.62	--
23	238.7	1092	1572	"	13.1	"	1865	+0.19	+0.08
24	245.1	1036	1036	"	12.7	16/4/2	1471	+0.42	--
--	248.55	--	--	--	--	--	--	--	--
25	251.7	990	1461	6.6	12.4	16/4/2	1486	+0.02	+0.12
26	258.1	950	950	"	12.1	"	1501	+0.58	--
27	264.4	930	1407	"	11.8	"	1519	+0.08	+0.11
28	270.8	918	918	"	11.4	"	1544	+0.68	--
--	274.26	--	--	--	--	--	--	--	--
29	277.4	900	1483	6.6	11.1	16/4/2	1565	+0.06	+0.11
30	283.8	875	875	"	10.8	"	1588	+0.81	--
31	290.1	847	1368	"	10.5	"	1613	+0.18	+0.20
32	296.5	812	812	"	10.2	16/2/2	1242	+0.53	--
--	299.97	--	--	--	--	--	--	--	--
33	302.9	775	1309	6.06	9.8	16/2/2	1436	+0.10	+0.13
34	308.7	740	740	"	9.5	"	1461	+0.97	--
35	314.5	708	1253	"	9.2	"	1489	+0.19	+0.19
36	320.4	670	670	"	8.9	"	1520	High	--
--	323.62	--	--	--	--	--	--	--	--
37	326.5	633	1183	6.06	8.6	16/2/2	1554	+0.31	+0.26
38	332.4	596	596	"	8.3	"	1592	High	--
39	338.2	560	1120	"	8.0	"	1635	+0.46	+0.33
40	344.3	520	520	6.3	7.6	"	1622	High	--
--	347.27	--	--	--	--	--	--	--	--

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TABLE 3-3. SUMMARY OF REAR SPAR WEB MARGINS (Sheet 1 of 2)

Panel	V.S.S. in.	q lbs/in	q_{net} lbs/in	b in.	a in.	Config. ±45/0/90	q_{cr} lbs/in	M.S. (Buckling)	M.S. (Cutout)
--	82.0	--	--	--	--	--	--	--	--
1	86.9	680	1002	8.6	8.6	20/6/2	2816	High	+0.75
2	93.8	660	1158	5.1	18.6	"	4263	"	+0.74
3	100.6	890	1467	8.5	18.3	"	1748	+0.19	+0.19
4	109.4	870	1119	9.1	11.8	"	1997	+0.78	+0.80
5	117.7	850	850	7.55	20.8	"	2082	High	--
--	121.45	--	--	--	--	--	--	--	--
6	124.5	830	1032	6.0	20.4	16/6/2	1949	+0.89	+0.65
7	130.5	815	815	6.0	20.1	"	1955	High	--
8	136.5	800	1003	6.0	19.8	"	1961	+0.96	+0.70
9	142.1	790	790	5.25	19.6	16/4/2	1955	High	--
--	145.71	--	--	--	--	--	--	--	--
10	148.9	600	758	6.4	19.2	"	1377	+0.82	High
11	155.3	600	600	6.4	18.8	"	1385	High	--
12	161.7	603	771	6.4	18.4	"	1394	+0.81	High
13	168.2	608	608	6.5	18.2	"	1363	High	--
--	171.42	--	--	--	--	--	--	--	--
14	174.7	610	788	6.43	17.7	"	1400	+0.78	High
15	181.1	614	614	6.43	17.3	16/2/2	1067	+0.74	--
16	187.5	618	808	6.43	17.0	"	1071	+0.33	+0.81
17	193.2	622	622	5.0	16.7	"	1669	High	--
--	197.13	--	--	--	--	--	--	--	--
18	200.4	480	636	6.43	16.3	"	1081	+0.70	High
19	206.3	485	485	6.43	16.0	"	1086	High	--
20	213.2	490	659	6.43	15.6	"	1092	+0.66	High
21	219.6	495	495	6.42	15.2	"	1102	High	--
--	222.84	--	--	--	--	--	--	--	--

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TABLE 3-3. SUMMARY OF REAR SPAR WEB MARGINS (Sheet 2 of 2)

Panel	V.S.S. in.	q lbs/in	q_{net} lbs/in	b in.	a in.	Config. ±45/0/90	q_{cr} lbs/in	M.S. (Buckling)	M.S. (Cutout)
--	222.84	--	--	--	--	--	--	--	--
22	226.1	497	679	6.43	14.9	16/2/2	1105	+0.63	High
23	232.5	500	500	6.43	14.5	"	1114	High	--
24	238.9	503	700	6.43	14.2	"	1120	+0.60	High
25	244.7	510	510	5.25	13.8	"	1609	High	--
--	248.55	--	--	--	--	--	--	--	--
26	251.8	390	554	6.43	13.5	"	1138	High	High
27	258.2	392	392	6.43	13.2	"	1147	"	--
28	264.6	395	575	6.43	12.8	"	1160	"	High
29	271.0	400	400	6.42	12.4	"	1177	"	--
--	274.26	--	--	--	--	--	--	--	--
30	277.5	402	603	6.43	12.0	"	1190	+0.97	High
31	283.9	405	405	6.43	11.7	"	1203	High	--
32	290.4	410	632	6.43	11.4	"	1217	+0.93	High
33	296.2	412	412	5.2	11.0	"	1736	High	--
--	299.97	--	--	--	--	--	--	--	--
34	303.2	212	212	6.55	10.7	"	1222	High	--
35	312.5	220	362	7.32	10.2	"	1078	"	High
36	319.9	230	230	7.48	9.8	"	1079	"	--
--	323.62	--	--	--	--	--	--	--	--
37	327.4	235	409	7.48	9.4	"	1114	High	High
38	334.9	242	242	7.48	9.0	"	1153	"	--
39	342.4	250	467	7.48	8.6	16/4/2	1586	"	High
40	349.8	255	255	7.48	8.2	"	1655	"	--
41	357.3	[illegible]	538	7.[illegible]	7.8	"	1735	"	High
42	364.2	270	270	6.42	7.4	"	2148	"	--
--	368.53	--	--	--	--	--	--	--	--

in Table 3-2 is +0.11. Peak tangential tensile stress at the edge of the hole in panel 1 was computed to be 58.718 psi at an angle of 130 degrees measured from the 0 degree reference angle. A computer program was used to determine the applied ply level strains and stresses and the resultant margin of safety. In panl 1, the maximum ratio of applied strain to allowable strain is 0.951 and occurred in the transverse tension direction. The margin shown in Table 3-2 is (1/.951) -1 = +0.05.

The lowest margin of safety in either spar cap was +0.40 at VSS 117.87 in the rear spar. Relatively high margins (approximately 1.0 or higher) were found in the stiffeners and in the fuselage joint. Fail-safe loads exceeded final design loads locally at approximately VSS 145 in the front spar caps in the bay between VSS 97 and VSS 145 in the rear spar web, but high computed margins verified by the H23A and H20 test results demonstrated that the spars have adequate strength for the fail-safe loads.

3.2 PROCESS VERIFICATION

The purpose of the process verification task is to develop and verify the elastomeric molded process (cure cycle) established for the fabrication of the front and rear spars.

3.2.1 Process Bulletin, PB 80-580 - Molding of Spars

Considerable scatter has occurred in the compression stresses demonstrated by the small process control specimens cut out of the PRVT spars. The cross-section of these specimens is approximately 0.12 inch by 0.40 inch. They are supported in a potting compound cured inside steel rings, and the steel rings and potting compound are machined perpendicular to the specimen. An unsupported test section of approximately 0.5 inch between the ring is strain gaged for the purpose of applying a pure axial load during the test. This procedure has produced reasonably good compression test data where larger specimens were used, but as shown in Figure 3-3, the scatter in the PRVT process control specimens tested to date has been relatively large. A smaller number of "dog-bone" specimens have been tested in a modified FED STD 406 fixture, using an adapter to fix the ends and the scatter has been within the predicted range for test results. An additional modification was made to the

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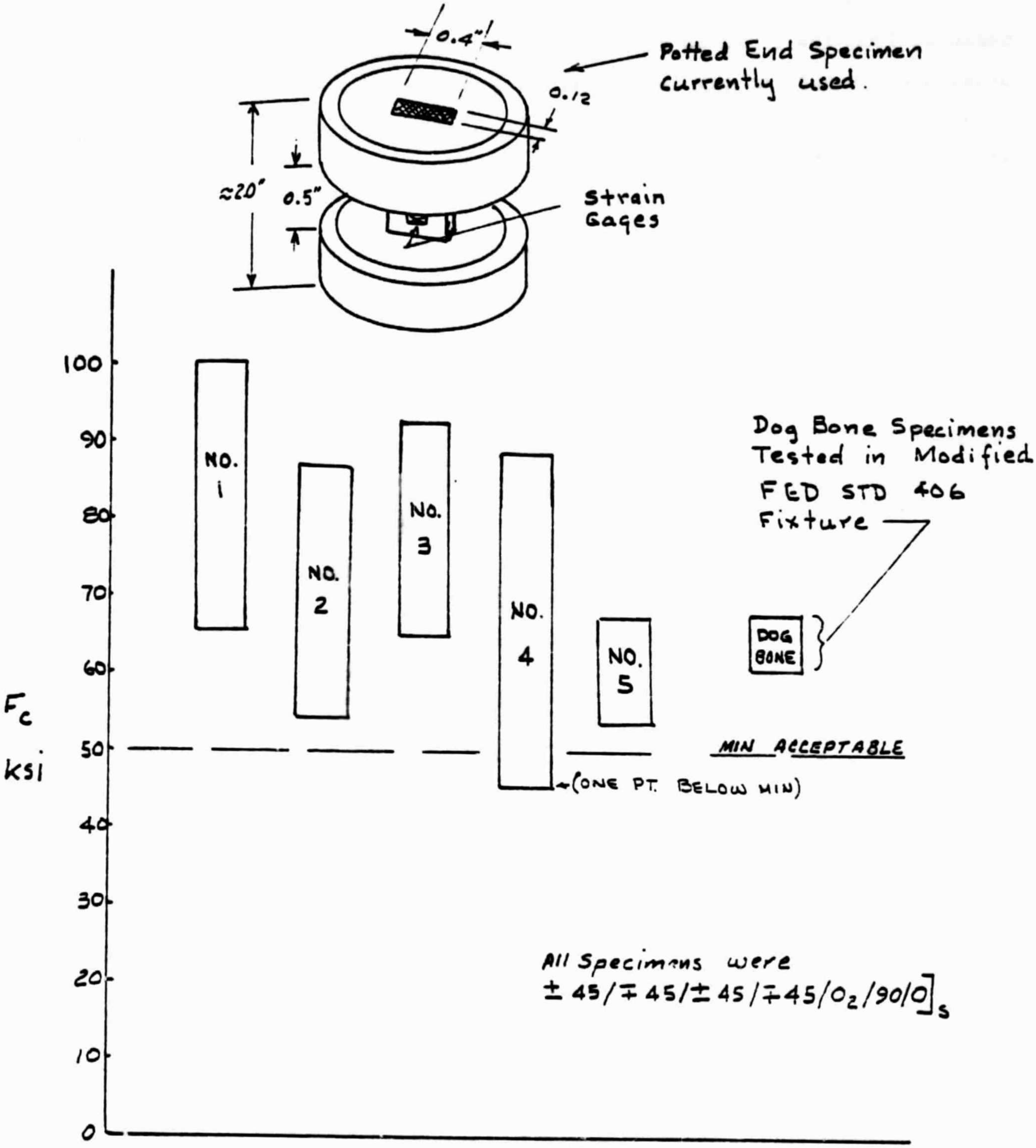

Figure 3-3. Compression Process Control Specimens from PRVT Spars

FED STD 406 test fixture that eliminates the support at the center of test specimen.

Additional investigations were made to determine if the small compression specimens could be damaged during preparation for test. A possible source of damage is that machining the steel rings may exceed the very low torque strength of the specimen. This damage could explain the one low point in all of the compression data obtained to date, but the larger number of high points in the 80 to 90 ksi range are not explainable. The allowable strength is 57 ksi and as indicated on Figure 3-3 the test results should fall in a range of 60 to 70 ksi.

3.3 CONCEPT VERIFICATION

The concept verification task provides for the substantiation of the structural integrity of selected areas of the ACVE and for the verification of analysis methods.

3.3.1 Rear Spar Test Specimens - Test Item H20

The last of the spar ancillary test specimens (H20) was tested at the Lockheed-Georgia Company during this reporting period. Two rear stub spar specimens were tested, one at room temperature-dry (RTD) and the other at 180°F preconditioned to 1 plus percent moisture. The RTD specimen sustained 244 percent of design limit load, and the wet specimen, tested at 180°F, failed at 272 percent of design limit load.

Both of the test specimens were identical to the lower 100-inches of the rear spar. THe joint base of these specimens used the same fittings as used in the L-1011 rear spar to fuselage joint. Holes were drilled in the spar flanges and fasteners were installed to simulate the attachment of the fin cover to the spar caps. The spar specimens were fabricated, processed and assembled in conformance with the processes and design requirements specified for the L-1011 ACVF spars and box assembly. A "Statement of Conformity" (FAA Form 8130-9) was issued prior to testing.

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3.3.1.1 Test Item H20 - Room Temperature Dry Test (RTD)

The loading conditions shown in Table 3-4 were used to simulate the design loads in the rear spar. Strain surveys were conducted up to limit load for each condition and compared with predicted strains. After the limit load strain surveys, conditions I and II were loaded to ultimate, and condition III was loaded to failure. Failure for Case III was predicted at 230 percent of limit. Actual failure occurred at 244 percent of limit load. Figure 3-4 shows the ultimate loads (150 percent limit) for load Case III and the maximum strains versus percent limit load. Failure occurred in the web where access holes and "D" shaped actuator holes are located near VSS 96.25. The calculated margin of safety for this area was 19 percent based on wet, elevated temperature allowables. Since typical test data usually shows strengths of 15 to 20 percent above allowables, and since the allowables were based on wet properties at temperature, the failure occurred at the approximate percent of limit load expected.

TABLE 3-4. H20 REAR SPAR STATIC TEST LOADS

	DESIGN		I			II			III		
V.S.S.	P_{cap} Kips	q lb/in	LP Kips	P_c	q	LP	P_c	q	LP	P_c	q
80	29.7		-	29.7		-	29.7		-	29.7	
		550			522			550			337
96.25	25.4		0	22.3		5.1	21.9		-13.1	25.4	
		980			550			338			980
121.35	14.5		-5.0	9.5		-5.6	14.5		19.1	1.6	
		840			840			645			73
144.58	10.0		23.9	-10.0		12.7	0		1.4	0	
		600			402			0			0
170.42	5.9		-7.4			0	0		0	0	

Refer to Figure 3-4 for locations of Load Points.

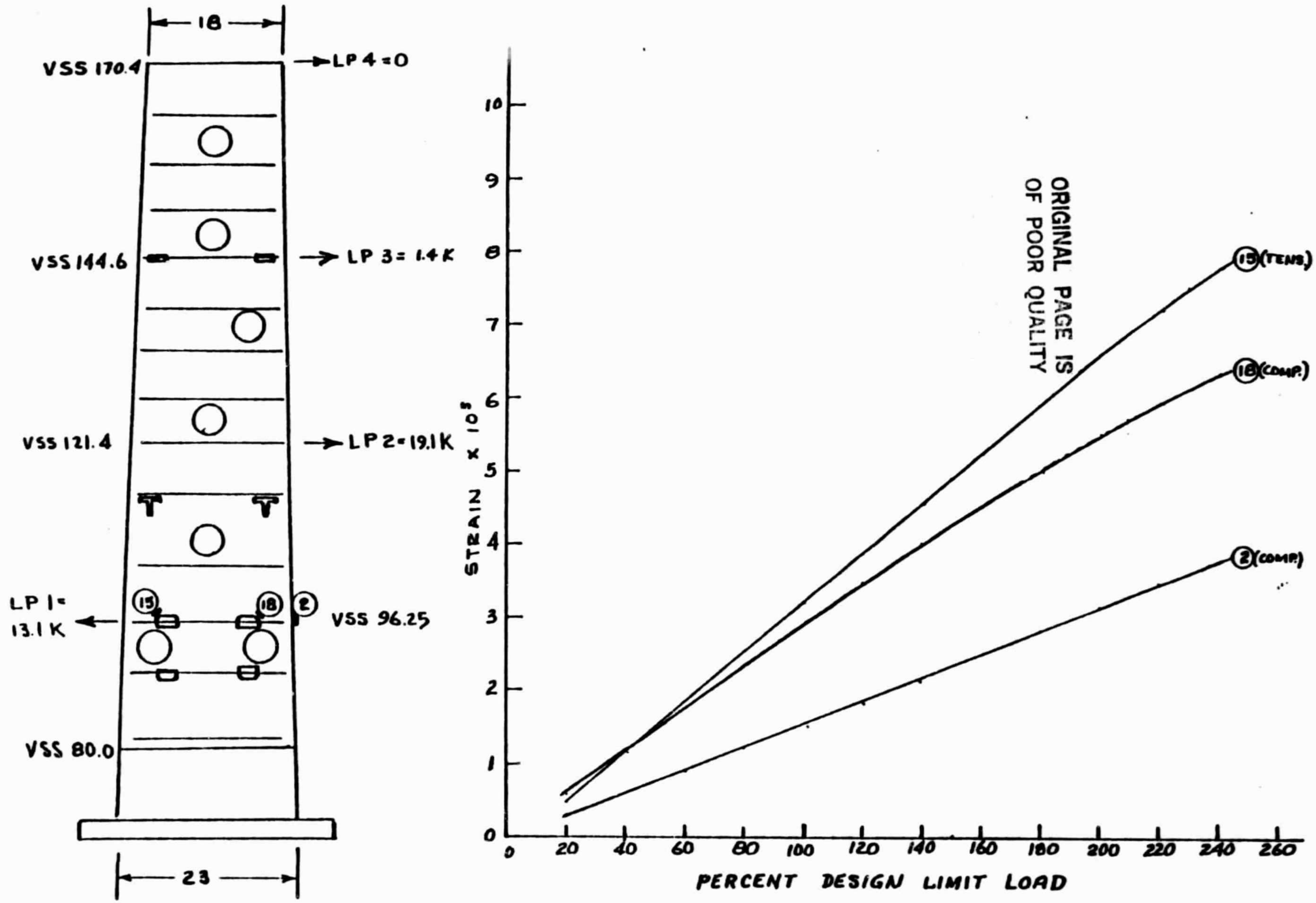


Figure 3-4. H20 RTD Load Case III Maximum Strains

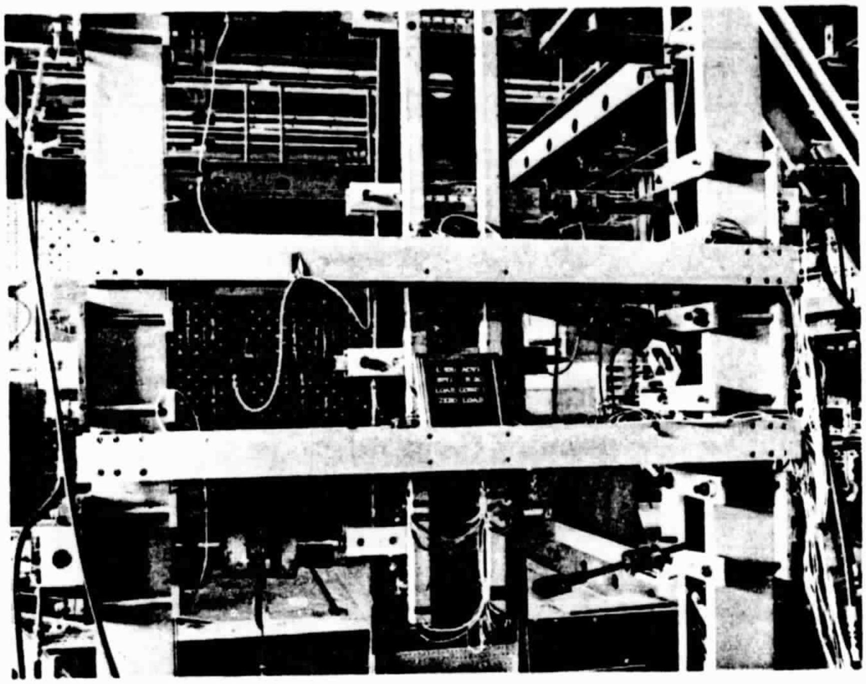
All areas of the H20 RTD specimen between VSS 80 144.6 were tested to loads equal to or greater than 150 percent of the loads shown in Table 3-4. Case III indicated the highest loads and this case was loaded until failure occurred in H20 RTD at 244 percent of limit load. Figure 3-5 shows the test setup for the dry H20 specimen and Figure 3-6 shows the loaded specimen. Figure 3-7 shows the specimen when failure occurred at 244 percent of limit load and Figure 3-8 shows the failure mode after the H20 RTD was removed from the test fixture. The faiure was slightly above the predicted 230 percent of limit. Strains were generally within the predicted range, and, overall, the test was considered very successful.

3.3.1.2 Test Item H20 — 180°F Wet Test

After completion of the dry test, a comparison of the test loads with the final, maximum ultimate spar loads revealed that the shear in the lower bay of the rear spar between VSS 80 and VSS 96 was 708 pounds per inch. This was considerably higher than the 550 pounds per inch (in the previous loads summary) which had been used as the H20 dry test load. The loads shown in Table 3-4 were revised to include the higher shear load. This revision was accomplished by revising Load Case II only. Cases I and III were not changed. The loading schedule applied to the H20 wet at 180°F specimen was as follows:

- Load Case I — Same as H20 RTD to 150 percent Limit
- Load Case III — Same as H20 RTD to 150 percent Limit
- Load Case II — Revised as shown in Table 3-5
- Load Case III — Same as H20 RTD to Failure

Table 3-5 shows the revised design loads and Case II loads that are compatible with the final design loads. Also shown in Table 3-5 are the maximum loads applied during the H20 RTD test. As indicated by the underlined loads, all design loads have been verified by the H20 RTD and the revised Case II loads applied during the H20 wet test.



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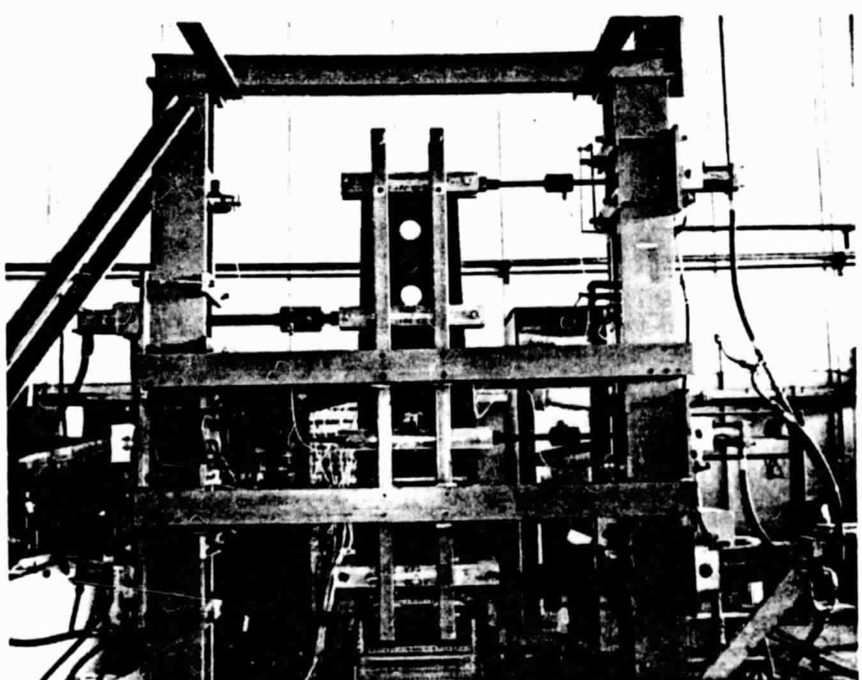

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Figure 3-5. Test Setup for H20 RTD

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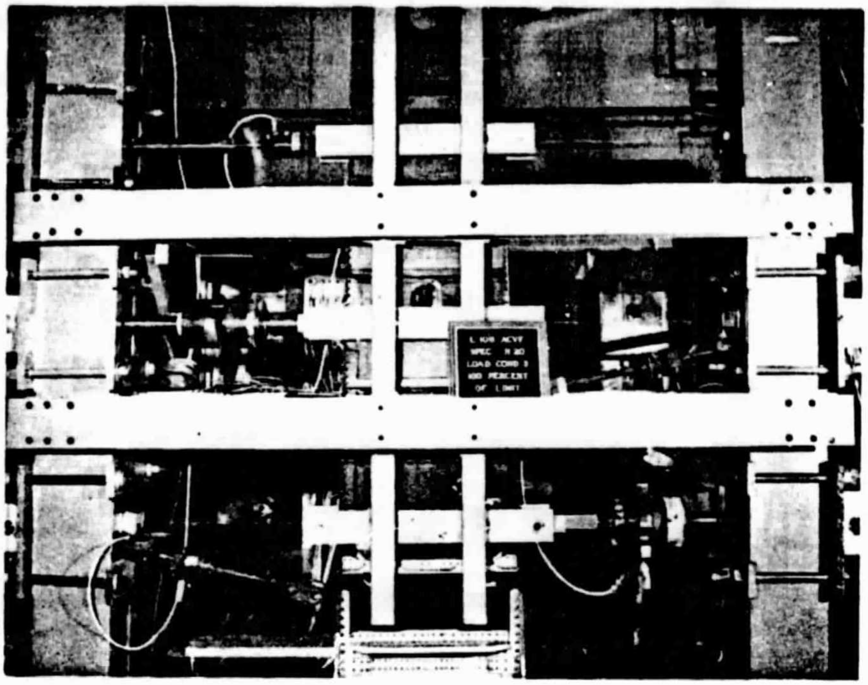

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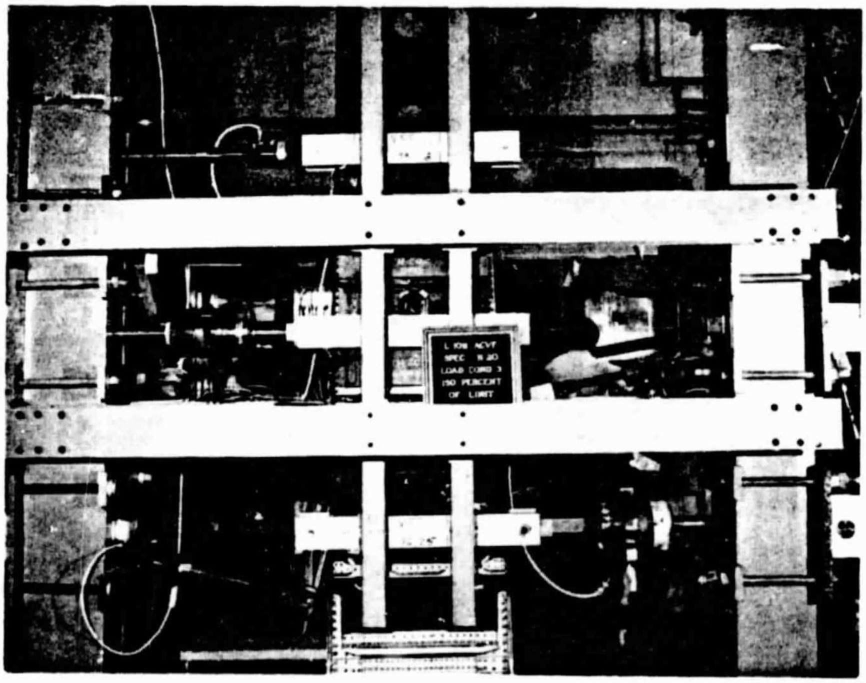

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Figure 3-6. H20 RTD at 100 Percent and 150 Percent Limit Load

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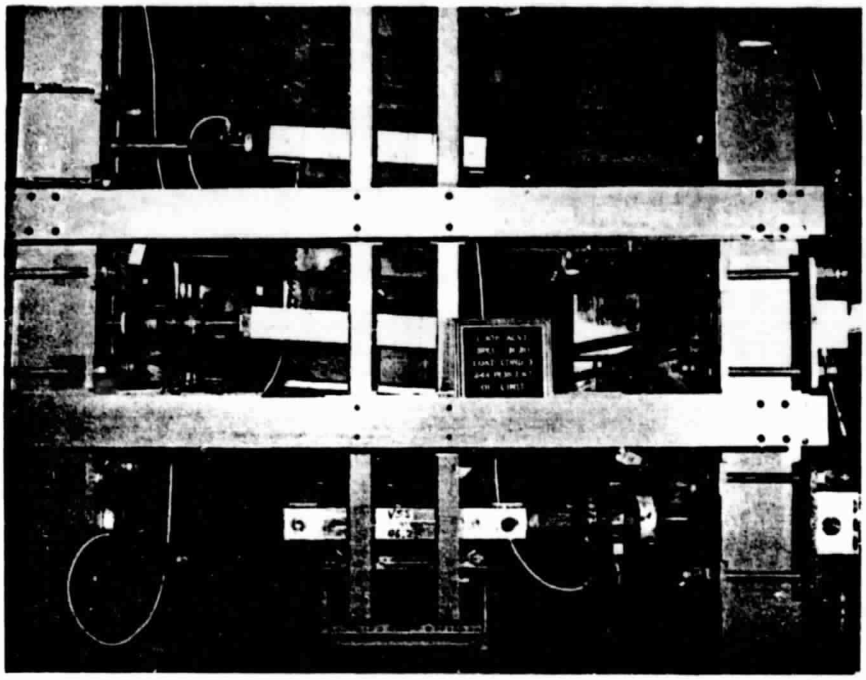

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Figure 3-7. H2O RTD Immediately After Failure (244 Percent Limit Load)

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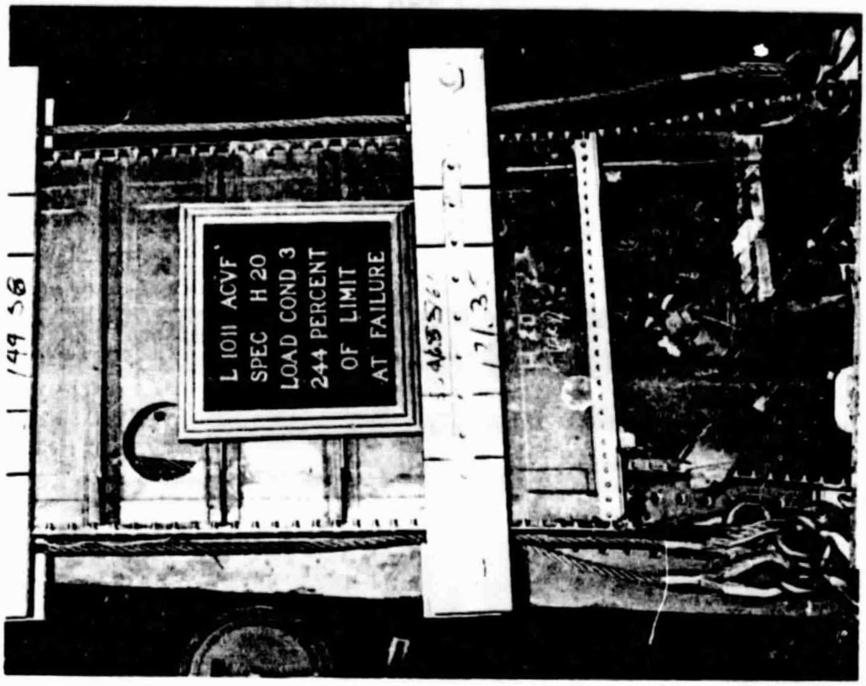

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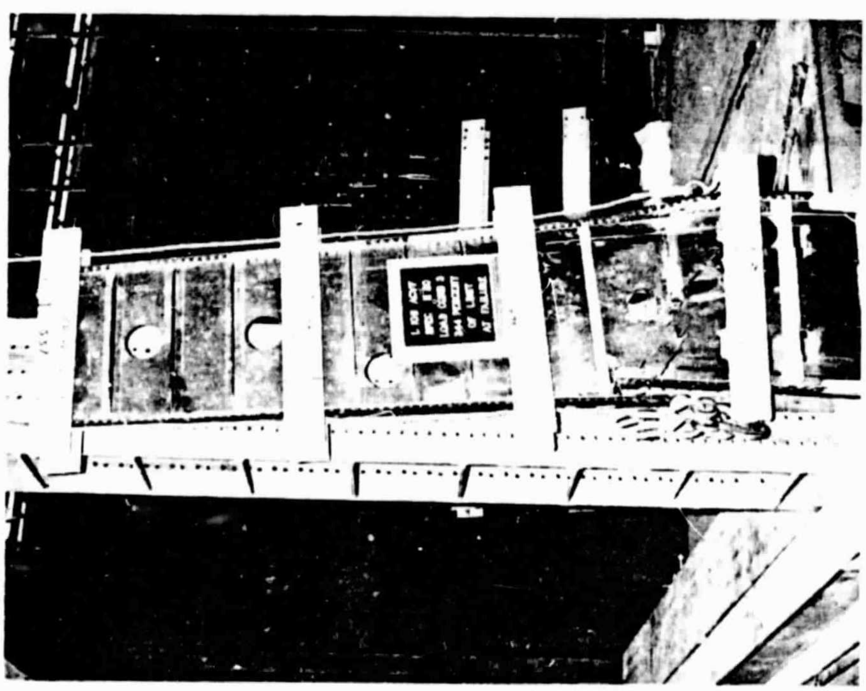

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Figure 3-8. H20 RTD After Removal from Test Fixture Showing Failure Mode

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TABLE 3-5. CHANGES TO REAR SPAR STATIC LOADS

Station	Design		Revised Case II			Max Load Applied to H20 RTD	
V.S.S.	P_{cap} Kips	q lbs/in	LP Kips	P_{cap} Kips	q lbs/in	P_{cap} Kips	q lbs/in
80	29.8		-	29.8		48.3	
		708			708		550
86.25	29.8*		0	18.9		41.3	
		875			752		1594
121.35	14.5		15.8	0		14.5	
		813					840
144.58	10.0		0	0		10.0	
		604					403
170.42	5.9		0	0			

*Refer to Figure 3-4 for location of load points.

A comparison was made of selected strains read during the wet and dry tests. Figure 3-9 shows this comparison for three gages read during load Case III. Strain gages 15 and 18 were located on concentrated stress areas in the "D" holes. The strains read during the wet at temperature test were considerably lower than those read during the dry test. Gage number 2 located on the spar cap was reasonably in agreement with both the dry and wet test conditions. Although the test data for H20 wet has not been plotted and analyzed, preliminary spot checks have indicated the gages followed the trend shown in Figure 3-9.

As a matter of interest, a minor repair was made to the cap flange on both of the H20 specimens. During cure, local areas of the cap flange were molded too thin. These dimensions were supposed to be 0.184 inches ± 0.014. In local areas, the flange was down to 0.160-inches. A thin 0.02 strip of

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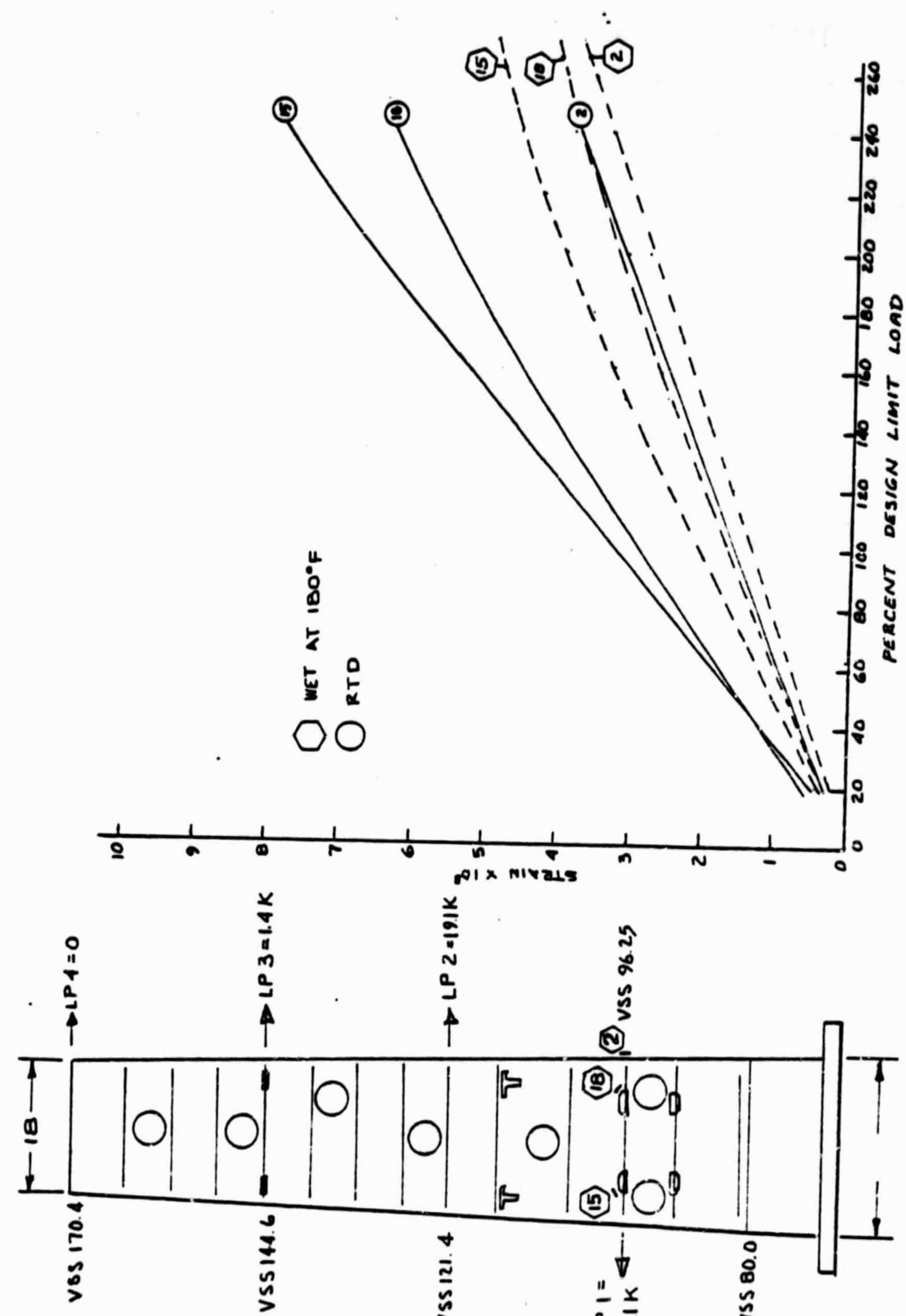

Figure 3-9. Comparison of Selected H2O Strains from RTD and Wet at Temperature Tests for Load Case III

titanium 6 Al 4V was bonded to the thin spots and fasteners normally used in the attachment of the fin cover to spar were installed. No failures of these repairs were detected in either the wet or dry series of H20 tests. This repair, if needed in the future, was verified by the H20 tests. Before making the repair, ultrasonic inspection had indicated no voids in the area to be repaired.

Test data accumulated during the H20 wet at elevated temperature test was reviewed, analyzed and compared to that of the H20 RTD specimen. Figure 3-10 shows the test setup for loading H20 while maintaining 1 percent moisture content and 180°F. The pictures in Figures 3-10 and 3-11 have the front and rear covers of the environmental chamber removed to show the spar wrapped and sealed in a nylon film bag. The plastic bag was used to retain the moisture content in the spar while it was heated to 180°F. Strains were recorded for the three test loading conditions. The critical load condition number 3 was loaded to 272 percent of limit before failure occurred. The picture on the right side of Figure 3-11 shows the failed spar after removal from the environmental chamber. Figure 3-12 shows a close-up of the failure mode as viewed from the front and aft faces of the spar. At failure, a deep buckle occurred between VSS 97.2 and VSS 121.45. This buckle popped back into the web plane during removal of the spar from the environmental chamber.

Figure 3-13 shows a comparison of the strains at the third from bottom access hole with those of the previously tested dry specimen. The compression strain shown by the solid line indicates the panel between VSS 96.25 and VSS 121.4 began to buckle at approximately 150 percent of limit load for both the RT dry and 180°F wet conditions. This correlated reasonably well with the stress analysis which predicted a margin of safety of +0.19 for shear buckling, as shown in Table 3-2. Although the analysis in Table 3-2 also shows a margin of safety of +0.19 for the critical ply, this M.S. is based on a transverse tension allowable of 5000 micro inches per inch and this failure can occur well in advance of complete panel failure. The predicted strain compared closely to the measured, tangential positive strain

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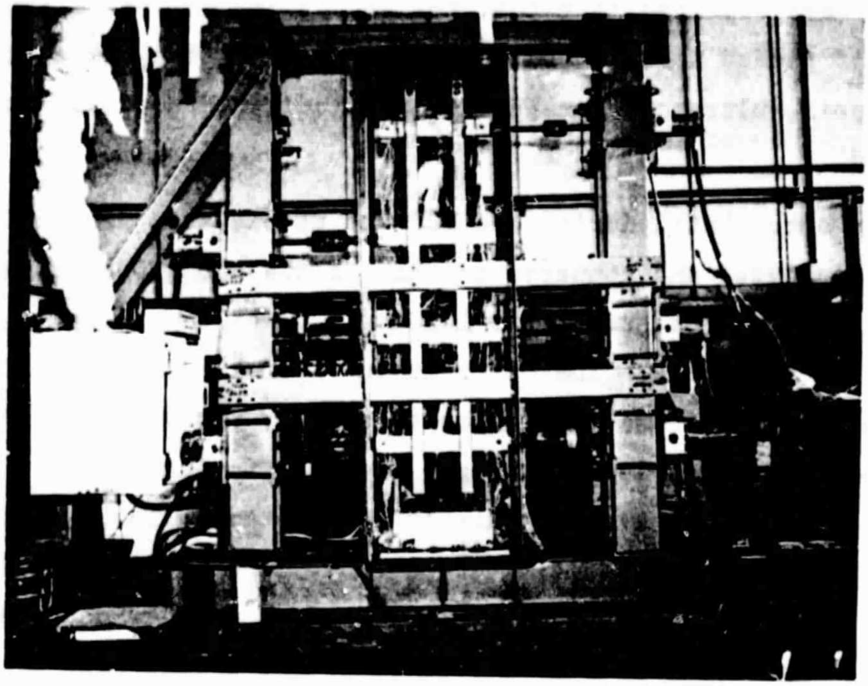

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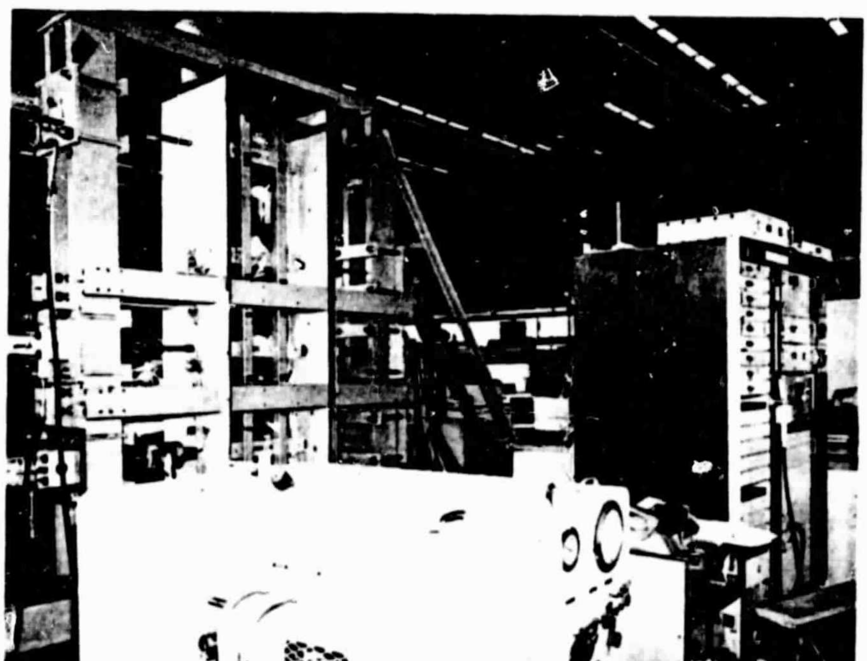

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Figure 3-10. Test Setup for Static Testing H20 Rear Spar Wet at 180°F (Covers of Environmental Chamber Removed to Show Spar)

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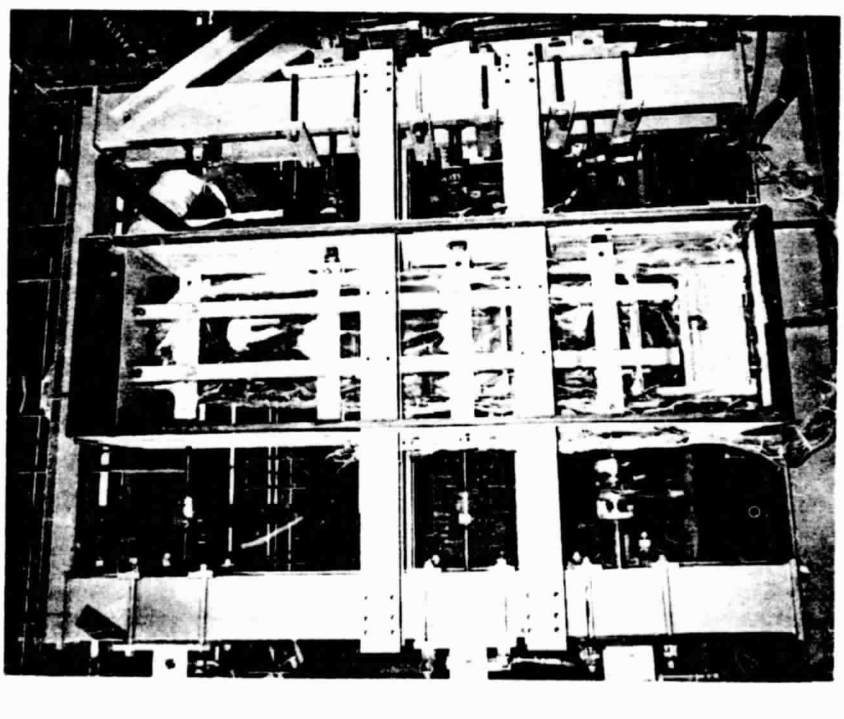

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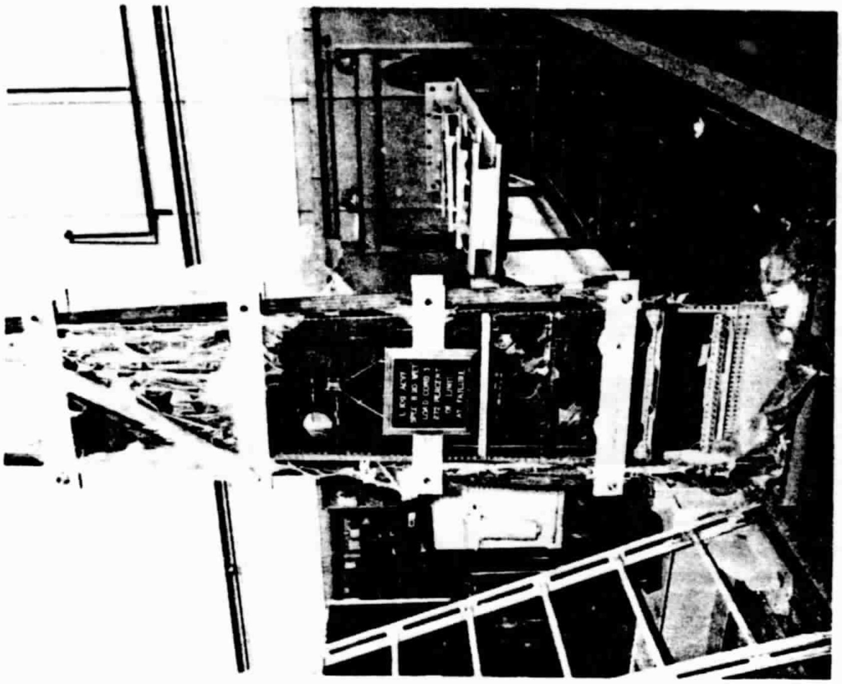

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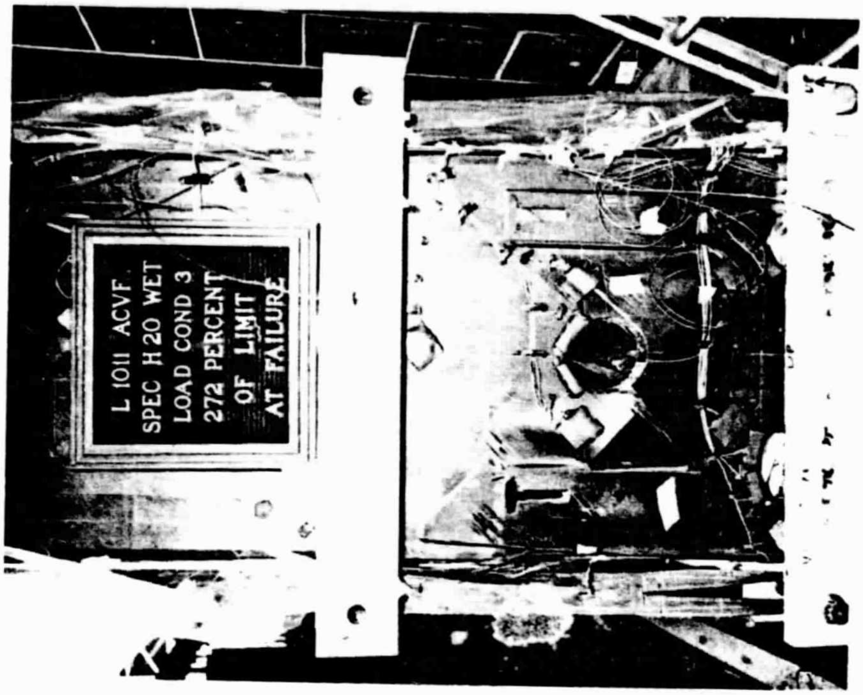
Figure 3-11. H2O Rear Spar in Test Fixture and After Sustaining 272 Percent of Design Limit Load



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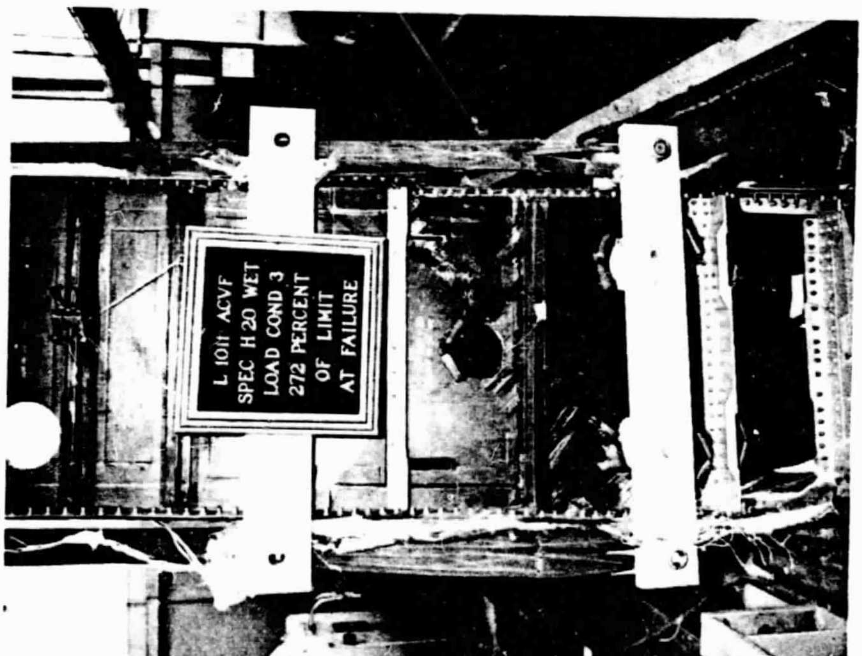

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Figure 3-12. H20 Failed Specimen Viewed from Forward and Aft Sides

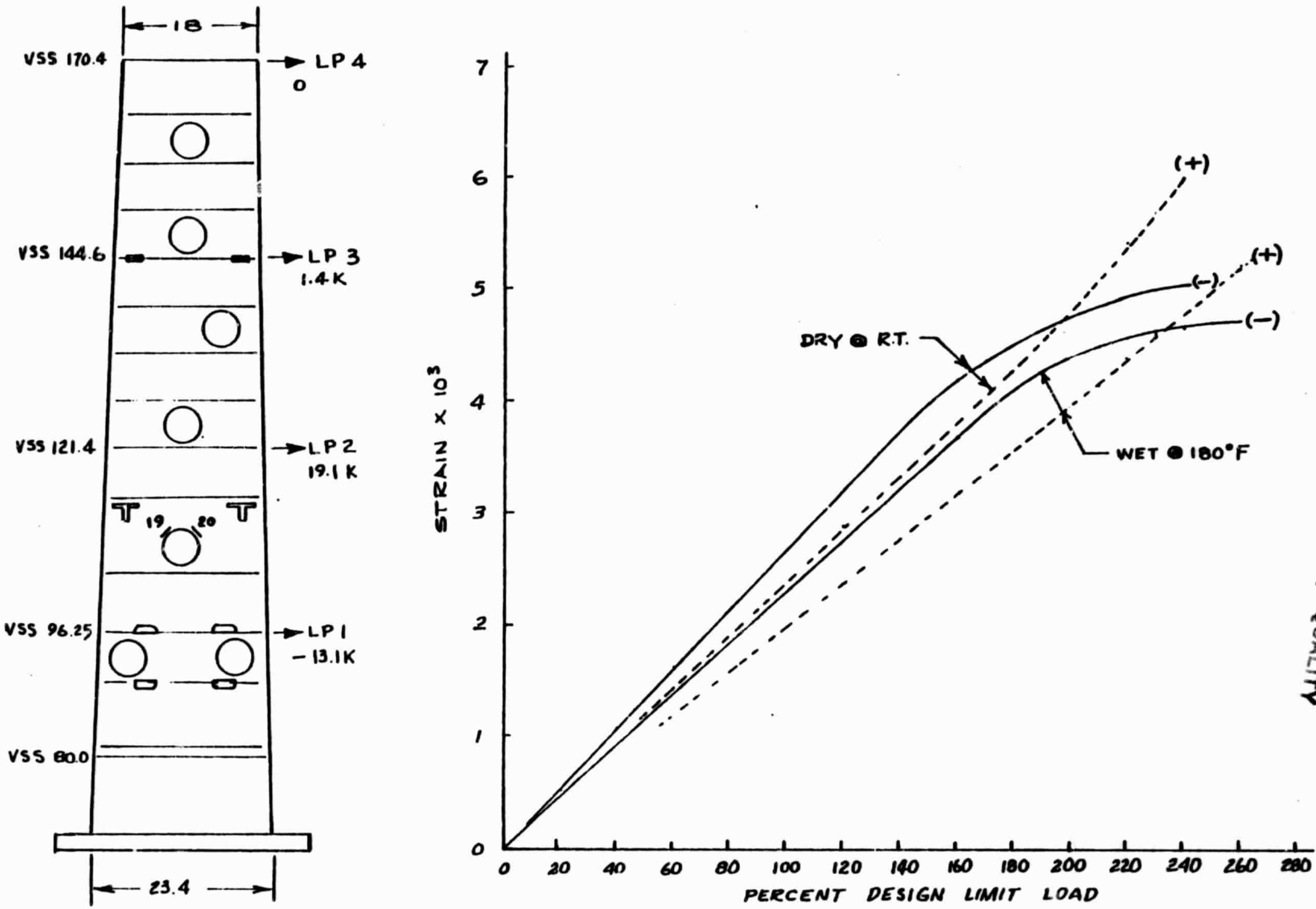

Figure 3-13. Comparison of H20 Strains at Access Hole (Gages 19 and 20) for Load Case III

shown in Figure 3-2. The predicted margin for this strain was +0.80 as compared to the actual failure of +0.81 = (272/150-1) for the wet specimen and +0.63 = (244/150-1) for the dry specimen. The close correlation with analysis indicated that the rear spar performed very close to the criteria of no buckling or transverse failures below design load, and the high, ultimate failure loads are not necessarily a valid indication of high margins of safety nor over strength design but reserve strength after partial failures.

3.4 QUALITY ASSURANCE

3.4.1 Laboratory Tests

A spot in the web of H20 unit number one (wet test at elevated temperature) indicated a 3/8-inch diameter void. After completion of the test and disassembly of the test setup, this questionable area was cut out of the spar web and sent to the Engineering Test Laboratory for microscopic examination. Also, selected thick and thin areas cut out of the flanges of the spar caps were sent to the laboratory for checks of resin content. Quality is holding the paperwork open for H-20 units 1 and 2 until the lab completes its evaluation of these specimens.

SECTION 4

PHASE III - PRODUCTION READINESS VERIFICATION TESTS

The ACVF program does not include flight service evaluation but alternately provides for multiple large-scale subcomponents of the structure for evaluation of variability in static strength and for assessment of durability under extended-time laboratory tests involving both load and environment simulation. The production readiness verification program (PRVT) is supplemental to the ancillary test program. These tests are designed to provide information to answer the following questions:

- What is the range of production qualities that can be expected for components manufactured under conditions similar to those expected in production, and how realistic and effective are proposed quality levels and quality control procedures?
- What variability in static strength can be expected for production quality components, and are the margins sufficient to account for this variability?
- Will production quality components survive extended time laboratory fatigue tests involving both load and environment simulation of sufficient duration and severity to provide confidence of in-service durability?

The questions are not primarily directed towards basic material properties. It is believed that the combination of service experience on secondary structures and coupon tests in the ancillary test program provide confidence in durability of the basic material. The questions are directed instead to the realities of production quality as influenced by cost objectives and by scale-up and complexity effects which will cause structural quality to differ from that represented by idealized small coupons.

On each of two key structural elements of the ACVF, ten static-strength tests and ten durability tests will be conducted. One element will represent the front spar/fuselage attachment area, and the other element will represent the cover/fuselage joint area.

4.1 TEST SUPPORT

4.1.1 Durability Test Facility

The facility planning has been completed and procurement and installation of the necessary hydraulics, electrical, water and drain hookups have been initiated.

The environmental chambers are in an advanced stage of construction at the vendors facility. Delivery of all four chambers is scheduled during October.

The spar and cover test frames are essentially complete. Final placement cannot be accomplished until the machinery package is placed in the test area. The test frames can then be positioned and the hydraulic, plumbing and electrical hookup accomplished.

The computer control system development is on schedule with all hardware complete. Figure 4.1 shows the computer console. The left bay from top to bottom contains the DAC monitor panel, computer controlled dump, relay chassis, analog/digital interface chassis, HP21MX E Series mini computer, and the 24 volt/30 amp power supply. The right bay contains the NEFF model 620 series 300 signal conditioner. The series 400 multiplexer/ADC and a second series 300 signal conditioner. To the left of the consoles is the high-speed printing terminal and to the right is the intelligent video terminal. All major interfaces within the consoles have been completed except for the signal conditioning.

Figure 4-1. Computer Consoles Showing Assembled Systems

4.1.2 PRVT Test Plan

The PRVT Test Plan has been completed and approved for implementation.

The plan describes the environmental spectra consisting of thermal cycling, humidity cycling, and load cycling. The basic thermal cycle is shown in Figure 4-2 which also shows the humidity variation. The cycle is presented for a 24-hour period.

The upper bound of temperature specified is 140°F, which was selected on the following basis. The thermal cycle used in the test represents about 20 percent of the total cycles expected in one lifetime. The ambient temperature was thus assumed to be that exceeded on the average 20 percent of the time, or an ambient of 80 to 85°F based on the temperature exceedance data contained in Figure 4-3. This ambient temperature range converts to a

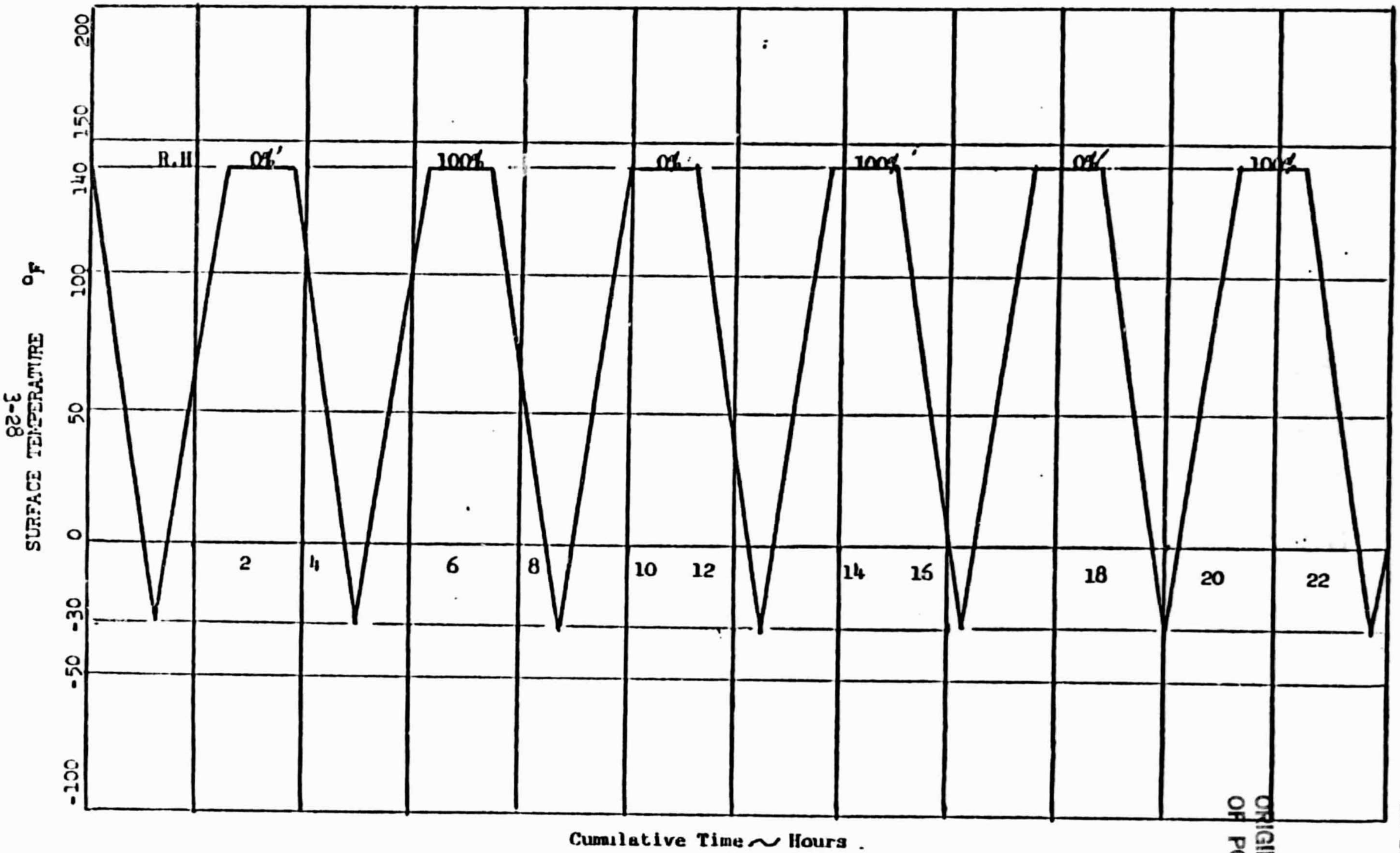

Figure 4-2. Environmental Thermo/Humidity Spectrum

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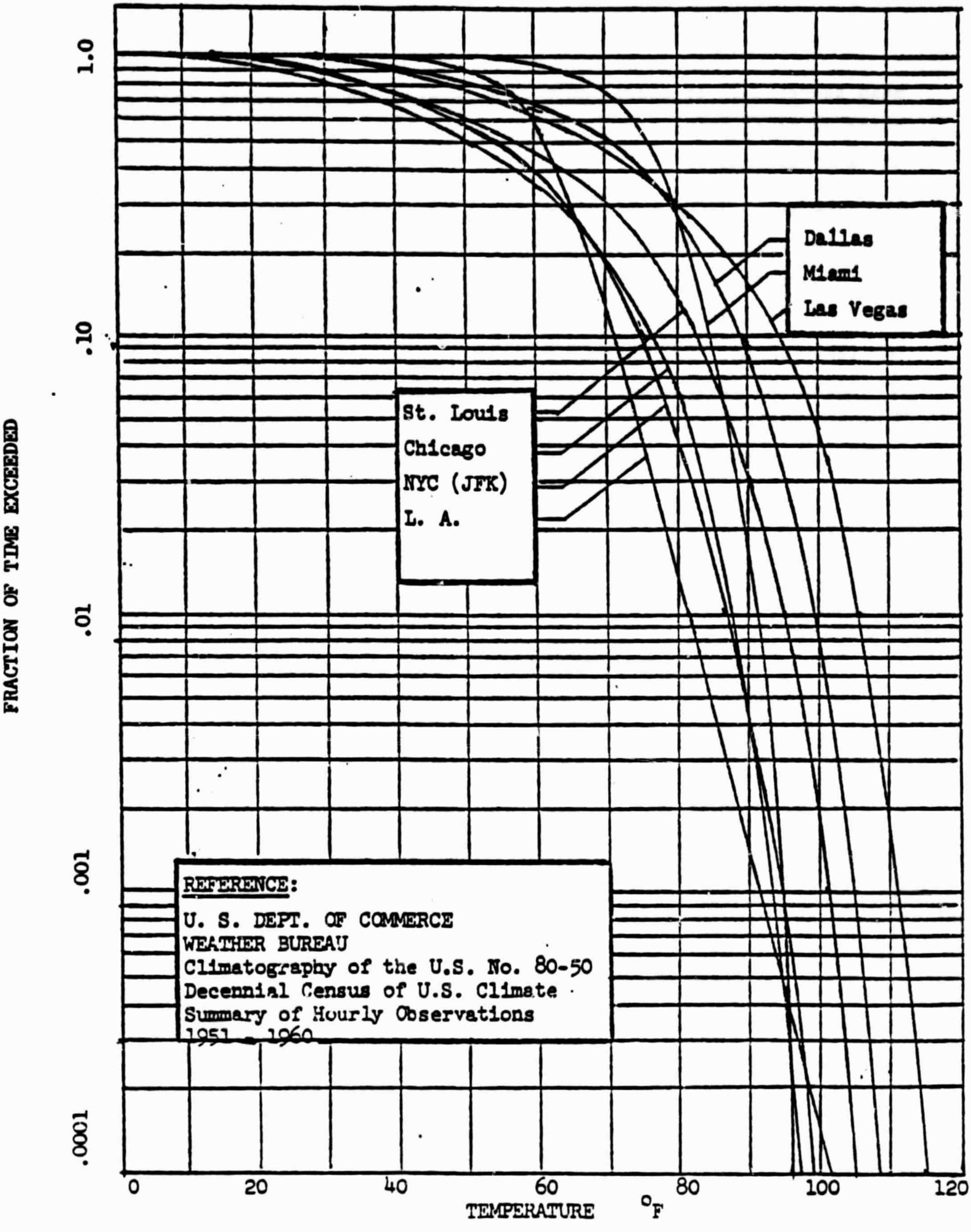

Figure 4-3. Temperature Exceedance

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skin temperature of about 140°F if a painted fin is assumed, with the darker color of paint predominating, such as the logos of TWA, British Airways or Eastern Airlines.

The lower bound was selected to be certain that the moisture in the laminates will be fully frozen prior to beginning the heating cycle. This will ensure the maximum volumetric expansion of the laminate working against the metal fasteners. Further, in the fully frozen state, no moisture transfer takes place. The thermal cycling in test H12A was from 160°F to -65°F and there was no adverse effect on the specimens compared with the specimens fatigued without thermal cycling. The aerodynamic heating effect makes -65°F a rare occurence for fin structure.

The relative humidities were chosen at 0 percent and 100 percent to represent flights between Miami and Las Vegas and to exercise the moisture gradients between layers of the laminate to a maximum. During the flight portions of the cycle chamber ambient humidity will depend on temperature.

The four environmental chambers are divided into three groups for thermal cycling. Figure 4-4 shows how the cycles for the three groups are staggered so that one refrigeration system can be used for all three groups.

The individual thermal cycle is shown in more detail in Figure 4-5. The average cooling and heating rates will be 2.5 degrees per minute. Loads cycles will be applied at three points in the cycle. These represent the climb phase with loads applied between 80°F and 40°F, the cruise phase with loads applied between 0°F, -30°F and 0°F, and the final phase is the descent with loads applied between 40°F and 80°F. Climb and descent loads are applied before freezing and after thawing respectively. The more severe loading is applied in the descent phase. The loading spectrum is presented in Table 4-1 and represents 36,000 flights of loading. The spectrum is similar to that used in other fatigue tests during the ACVF program but has additional low load cycles.

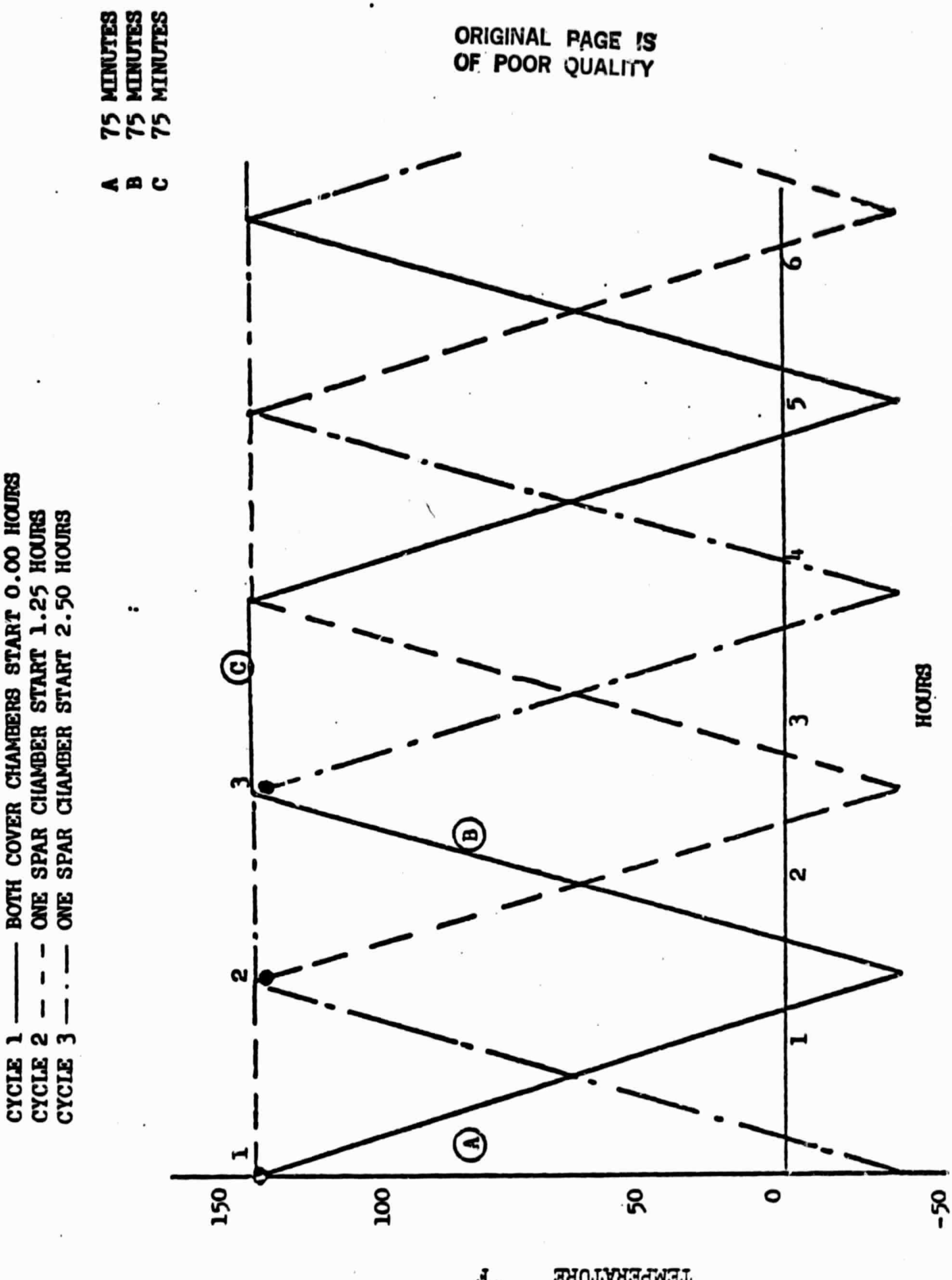

Figure 4-4. Cycle Sequencing

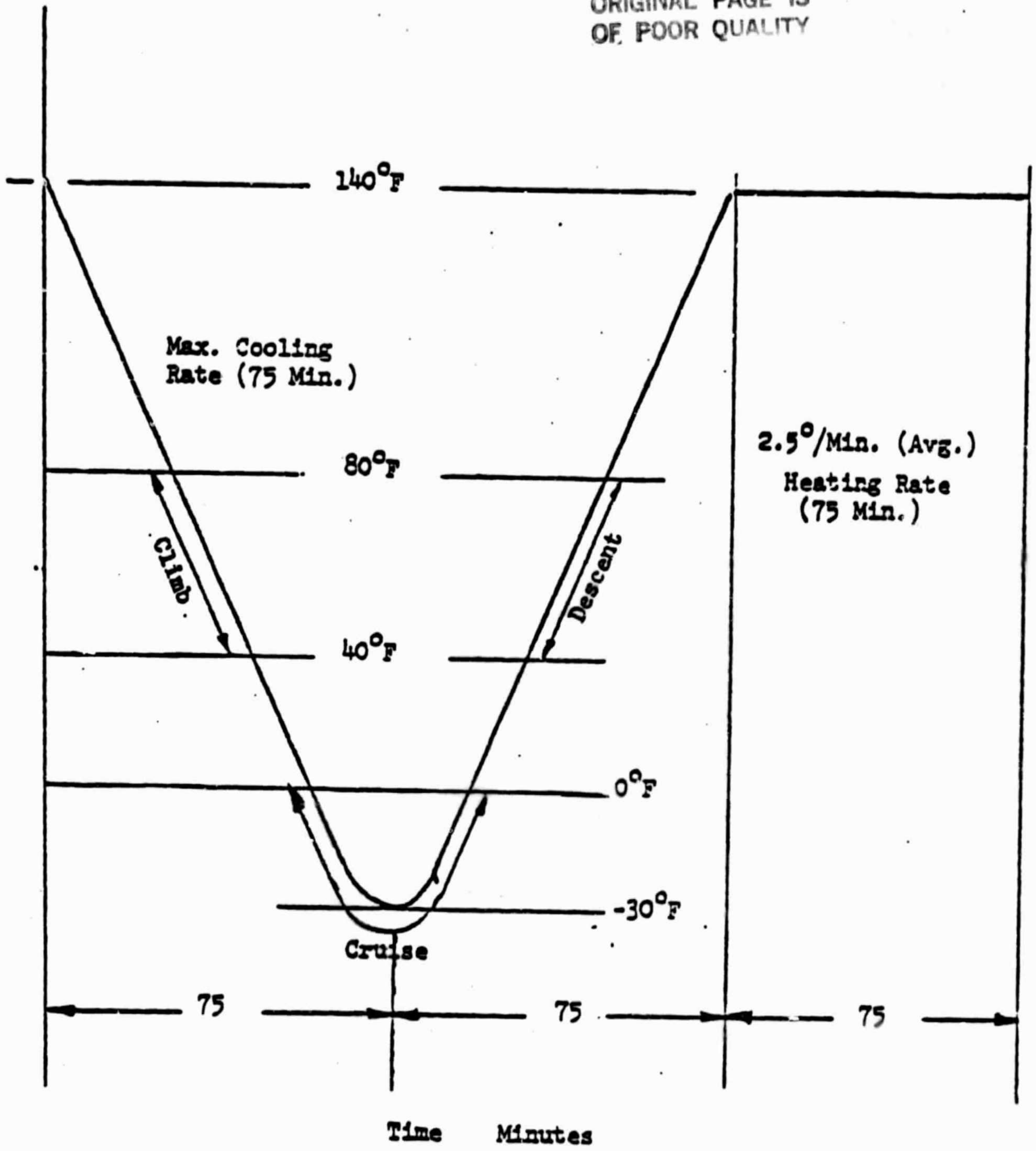

Figure 4-5. Schematic of Typical Thermal Cycle

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TABLE 4-1. LOAD SPECTRUM

% LIMIT LOAD	N	Σ N	FLIGHT PHASE	THERMAL CYCLE						
				1	6	58	290	1450	2900	5800
15	168,184	198,218	Cl	9	9					
			Cr	2	2					
			D	14	13					
23	24,044	30,034	Cl		7	2	1			
			Cr		3	1				
			D		14	5	2			
31	4,192	5,990	Cl		1	1		1		
			Cr		1					
			D		2	2	1	1		
38	1,245	1,798	Cl			1	1	1		
			Cr				1	1		
			D		1	1	1	2	1	1
46	328	533	Cl			1		1		
			Cr			1				
			D			1	1	1		
54	134	225	Cl					1		
			Cr					1		
			D			1	1	1	1	
62	43	91	Cl				1			
			Cr							
			D				1		1	1
69	28	48	Cl					1		
			Cr							
			D				1	1		
77	9	20	Cl					1		
			Cr							
			D					1		1
81	3	11	D						1	1
85	3	8	D						1	1
88	3	5	D						1	1
92	1	2	D							1
100	1	1	D							1
Count				25	53	17	12	15	6	8
Multiplier				5,800	966	100	20	4	2	1

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In addition to the given environmental spectrum, at convenient and dispersed times during the 3-1/2 years the temperature of the ground portion of the cycle should be raised to 160°F 40 times and 180°F 10 times with a humidity at both temperatures of 20 percent. The latter conditions will simulate the maxima expected infrequently in service.

The environmental spectra are intended to accomplish two primary objectives. The first is to provide large changes in moisture distribution through the plies of the laminates and the second is to produce some acceleration of the testing by simulating the equivalent of 36,000 flight cycles in the 5800 applied cycles.

4.2 PRVT SPAR FABRICATION

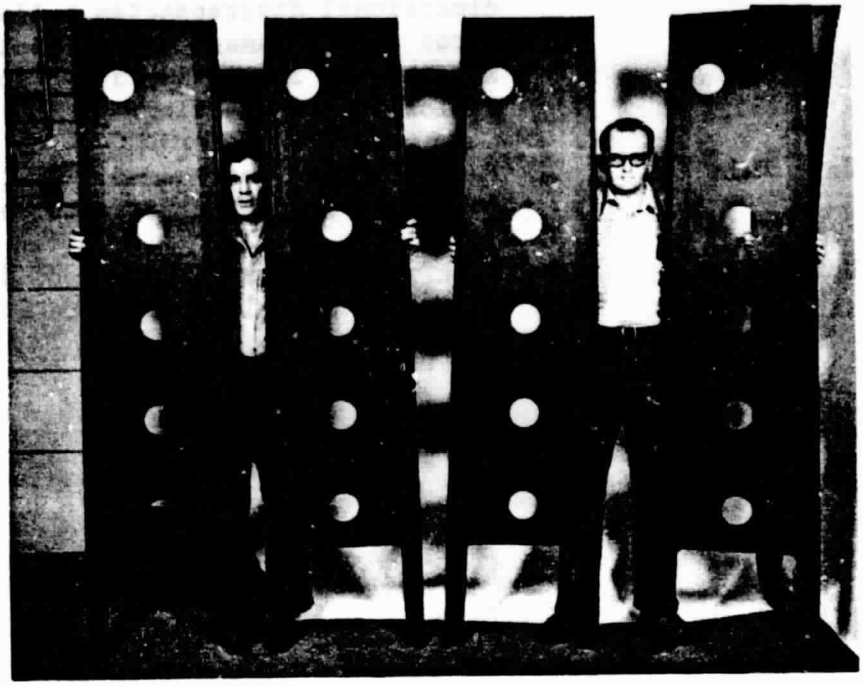
The first lot of four PRVT spars shown in Figure 4-6 were shipped to the Lockheed-California Company. Spar numbers 5 and 6 of the second lot were completed and number 7 is being cured. Spar numbers 5 through 8 are scheduled to be shipped by mid-October. Production rate of the PRVT spars is now one per week and a gradual reduction in weight has been shown from the first spar at 17.4 pounds to a 17.0 pound weight for number 6. This reduction in weight is attributable to a gradual improvement in tolerances.

4.3 QUALITY ASSURANCE

Quality participated in coordinating FAA and AF acceptance of the PRVT specimen numbers 1 through 4 and of the associated metallic details that required FAA conformity inspection.

Even though not a contract requirement, the full size front spar fiberglass tool try and the graphite tool try parts have been followed very closely by Quality Assurance. Additional activity has been in the in-process inspection of material lay-up, trim and tool loading for PRVT specimen numbers 5 through 7. Status of those spars is as follows:

PRVT Unit 5 DR 232821 - Vacuum bag burst during cure. Minor NDI, process control and visual and dimensional discrepancies. DR is in MRB for corrective action.



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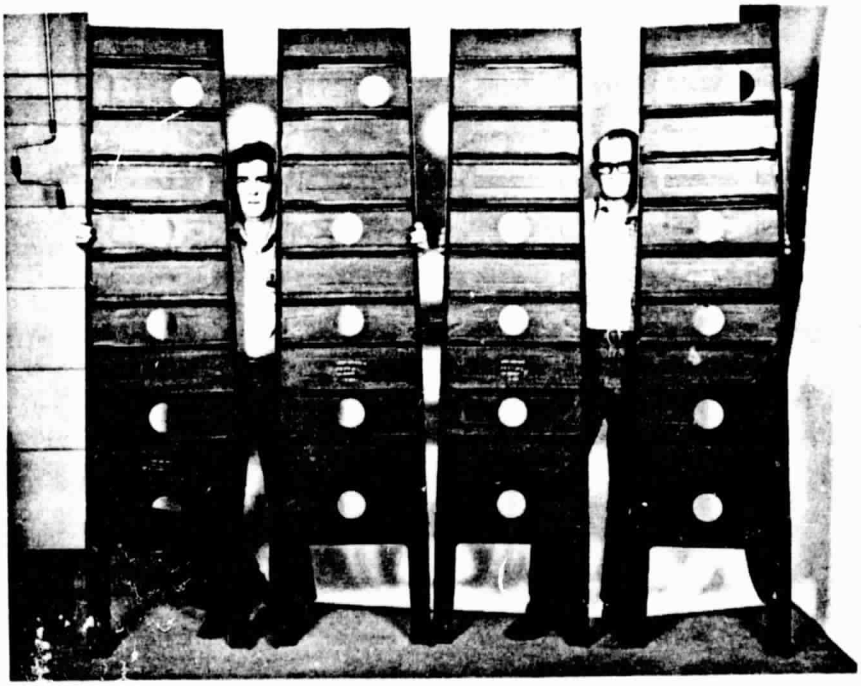

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Figure 4-6. PRVT Spars 1 Through 4

PRVT Unit 6 DR 203833	-	Minor NDI, process control, visual and dimensional discrepancies. Also a machining error caused damage to web section at access hole number 3. DR is in MRB for corrective action and disposition.
PRVT Unit 7	-	Part has been post-cured. Will be ultrasonically inspected 26 September 1978.
PRVT Unit 8	-	Part will be loaded into tool 25 September 1978 and go to autoclave for cure 26 September 1978.

SECTION 5

PHASE IV - MANUFACTURING DEVELOPMENT

Tool manufacturing activity on the tooling required to produce full scale ACVF components is underway at both the Lockheed California Company (covers and ribs) and at the Lockheed Georgia Company (spars). The full scale tooling incorporates the tooling concepts proven during the Process Verification phase of the ACVF program.

5.1 COMPONENT TOOL DEVELOPMENT

5.1.1 Covers

Both full scale cover lay-up tools are in the completion phase in the tool shop. In addition to refinishing the tool surfaces and the addition of the "ramp" to mold the root end skin joggle, the following additional ACVF cover tooling elements are in work in tool design:

- Tool vacuum system
- Thermocouple attachments
- Bladder venting system
- Lay-up templates
- HAT lay-up tools and prebleed carrier
- HAT locating details
- Access stands
- Trim and NDI fixtures

A schedule for each of these tooling components is being negotiated to support tool try lay-up in December 1978, with full scale cover fabrication to follow early in 1979.

5.1.2 Ribs

Although the basic tooling concepts for each of the rib types has been developed and proven in fabrication of development parts and components for test, there are still some alternate variations in tooling concepts which are being explored prior to the release of the tool orders for the 11 full-scale ACVF ribs. As these concepts are finalized on each of the basic rib types (truss, actuator, and solid web) within the next few weeks, the orders for all of the ribs of each rib type will be released for tool design finalization and tool fabrication.

5.1.3 Spars

The front spar tool was completed during the month of September. Figures 5-1 through 5-8 show the procedures used to pour and cure the rubber parts of the tool. Figure 5-1 shows the positioning of island blocks used to mold the rib attach angles and stiffeners on the tool base plate. Figure 5-2 shows the dummy web being fitted inside the tool cover on the flat island blocks that form the flat side of the web. Figure 5-3 shows the waxed island blocks. Waxing is the technique used to fill in the gaps between the room temperature rubber and the dummy parts. Dummy parts are made to the nominal thickness of the finished part. Prepreg laminates are thicker than cured laminates and the rubber is required to be set back from the laminate to allow for expansion of the rubber with increase in temperature before applying pressure to the part. In Figure 5-4, rubber is pumped into the lowered upper end of the tool cover to form the rubber blocks used to mold the forward cap flanges to spar web intersection. Rubber is mixed, decassed, and pumped into this cavity using an automatic rubber mixing machine. Figure 5-5 shows the rubber emerging at the raised end of the tool which is approximately 25 feet from the point where the rubber is pumped into the tool. The island blocks shown in Figure 5-1 have been turned upside down to fit into the tool cover shown in Figure 5-2. The base plate is removed exposing the cavities between the island blocks. Figure 5-6 shows the completed pouring of rubber around island blocks. After partial cure, the island blocks are removed as shown in Figure 5-7 and the rubber is cured in an oven as shown in Figure 5-8.

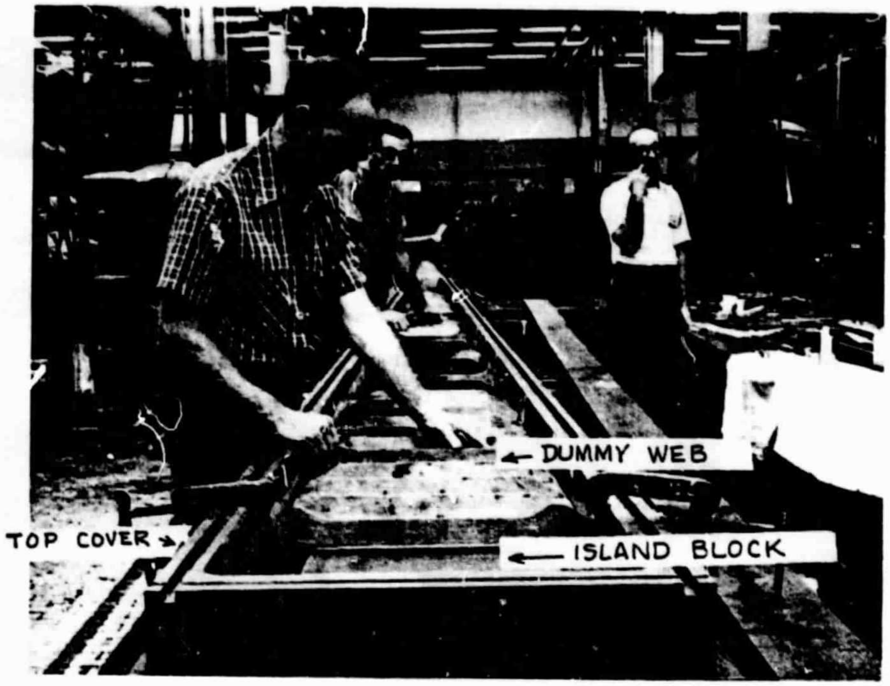

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Figure 5-1. Positioning of Island Blocks on Shim and Base Plate of Front Spar Tool

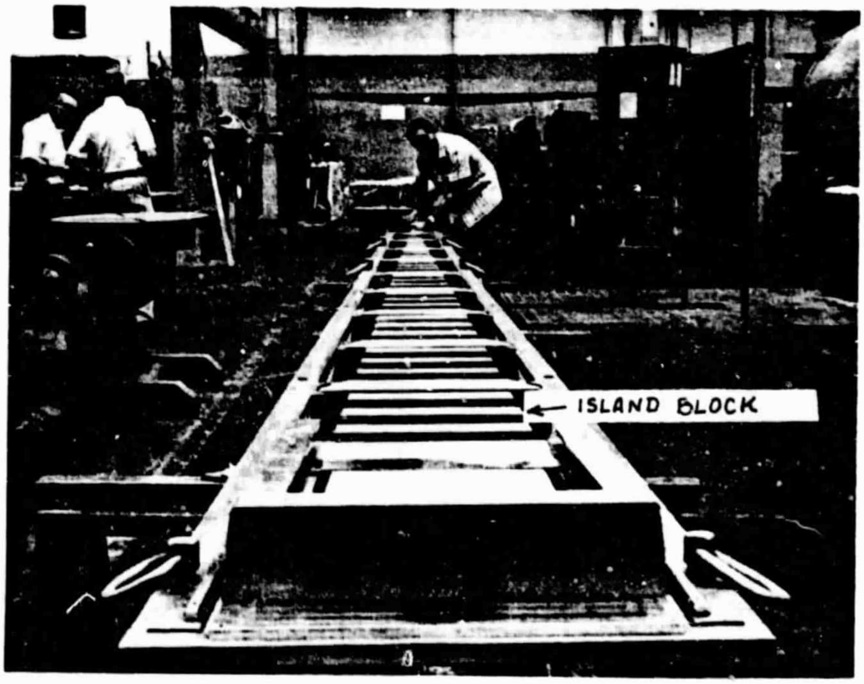

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Figure 5-2. Fitting Dummy Web on Island Blocks Inside Top Cover of Front Spar Tool

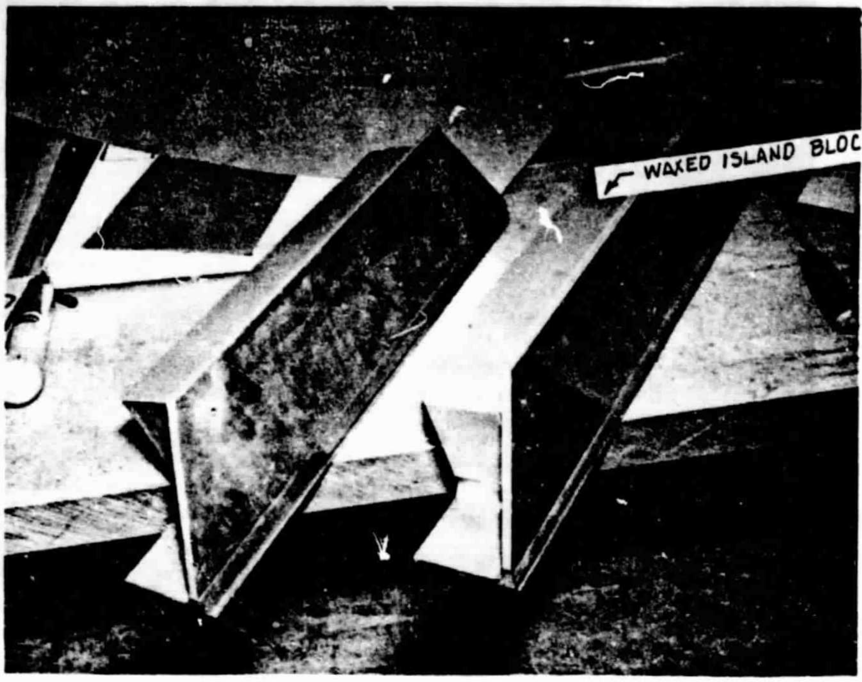

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Figure 5-3. Unwaxed and Waxed Island Block

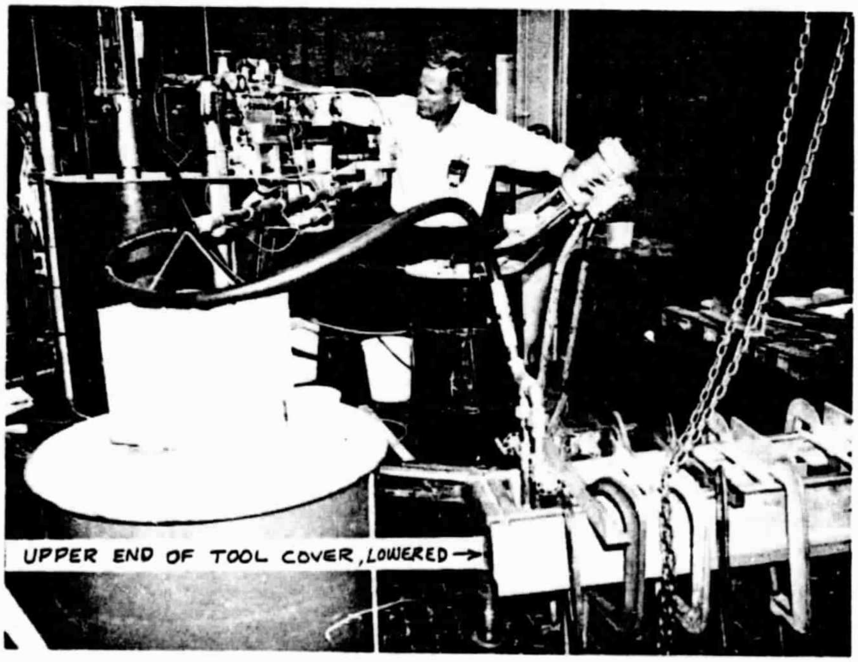

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Figure 5-4. Pumping Rubber into Lowered, Upper End of Tool Cover Using Rubber Mixing Machine

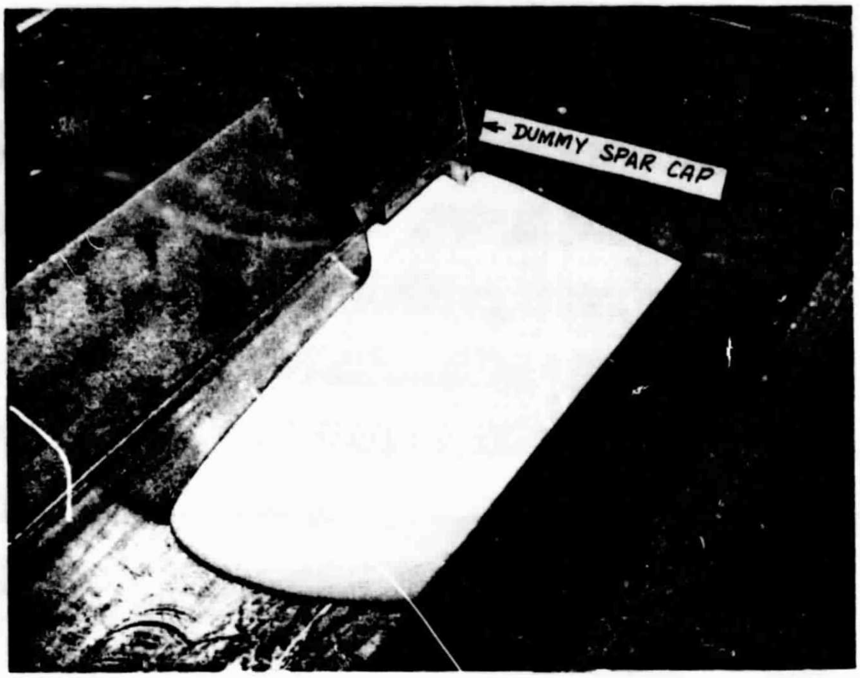

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Figure 5-5. Pressurized Rubber Pumped into Lowered, Upper End of Tool Cover Showing Rubber as it First Emerges at High End of Tool

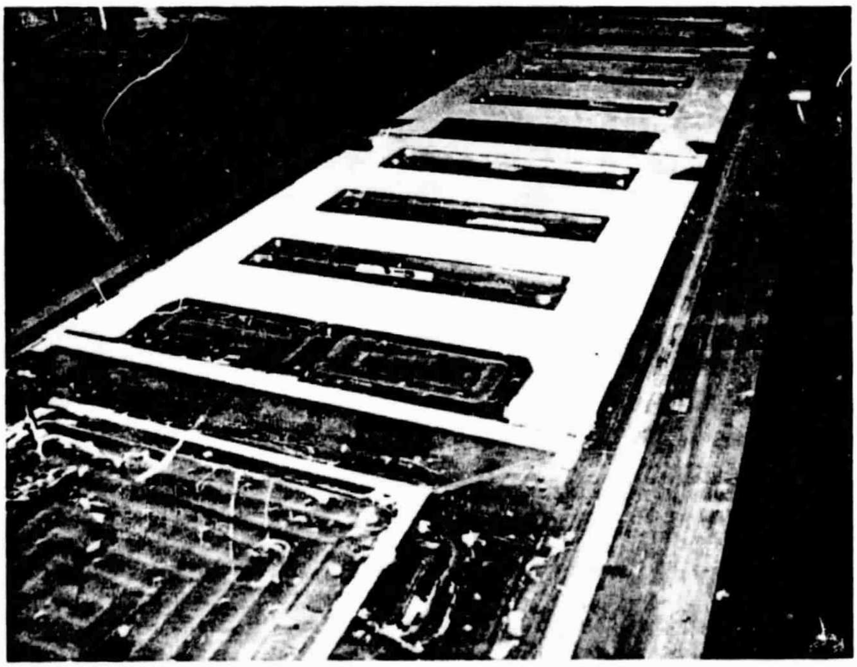

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Figure 5-6. Gravity Leveled Rubber Around Island Blocks Completed and "C" Clamps Removed

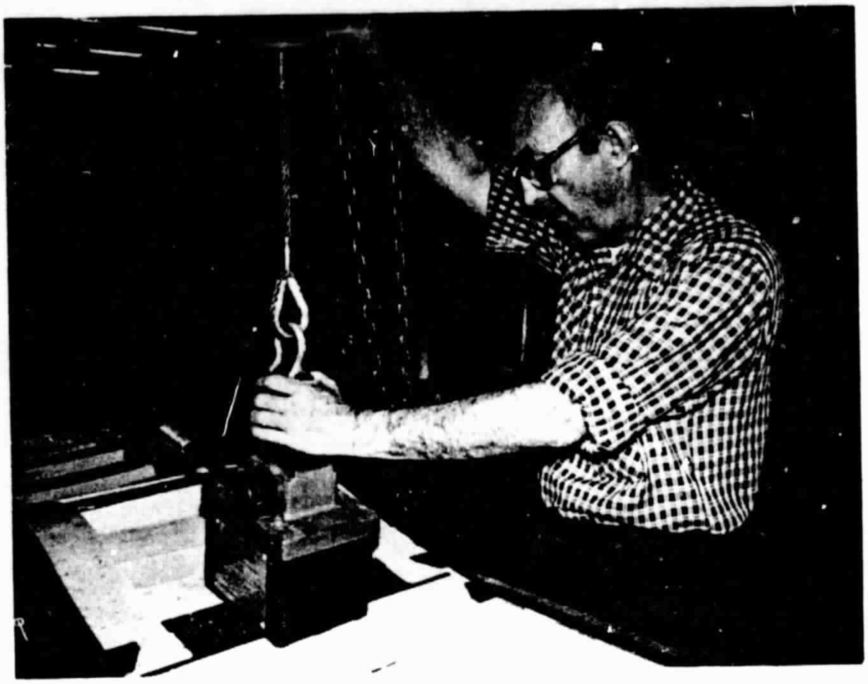

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Figure 5-7. Magnet Used to Remove Island Blocks

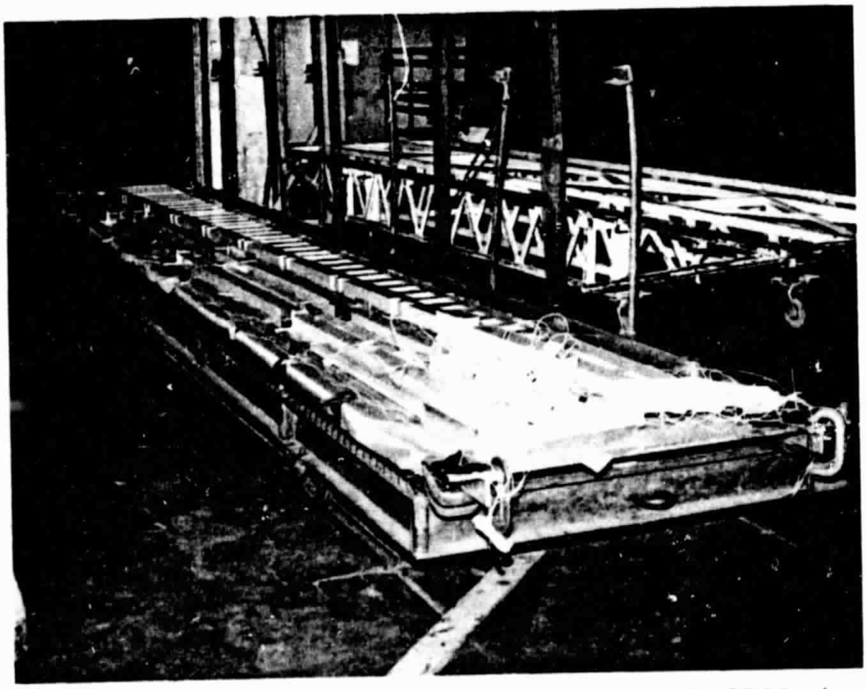

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Figure 5-8. Rubber for Front Spar Tool Removed from Oven After Cure

Steel parts are in the process of being machined for the rear spar tool. After completion of the steel parts, the rear spar tool will be assembled in a manner similar to the procedure used for the front spar tool.

The kitted laminates have been assembled in the front spar tooling. The tool is expected to be closed, bagged, and autoclaved the last week in (calendar) September. After completion of the autoclave and post-cure cycles, the spar will be turned over to inspection. After inspection, the spar will be cut into small specimens for structural testing.